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Distribution and abundance of Barndoor Skate *Dipturus laevis* in the Canadian Atlantic based upon research vessel surveys and industry/science surveys

Distribution et abondance de la grande raie *Dipturus laevis* dans l'Atlantique canadien basées sur des relevés de navire de recherche et des relevés de l'industrie/science

By / Par

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Abstract

Data derived from three principal sources in the Canadian Atlantic zone, spanning several decades, was examined for the occurrence of barndoor skate. The data reviewed included standardized research vessel (RV) surveys conducted by DFO, non-standard research vessel surveys and recent industry/science surveys. Despite the availability of over 80,000 RV and industry/science survey sets available for analysis, the frequency of occurrence of barndoor skate was very low (equal to 1.26%). In general, barndoor skates were more common in the 1950s and 1960s in comparison to later decades when they were sporadically encountered throughout the 1970s, and nearly absent during the 1980s to early 1990s. Since the mid-1990s, abundance has increased throughout the central/western Scotian Shelf and Gulf of Maine area. These patterns have been corroborated by seasonal surveys conducted by NMFS in US waters. Some persistent areas of concentration were evident, notably those associated with Georges Bank/Fundian Channel region, in the vicinity of Browns Bank, the central and slope waters of the Scotian Shelf and possibly the Laurentian Channel region. Concentrations that were evident early in data series but are not evident now include the eastern Scotian Shelf, Div. 3Ps and the southwestern slope waters of the Grand Banks. It was apparent from the industry/science surveys that barndoor skate were consistently captured at depths/locations beyond the standard research vessel surveys. This observation is in agreement with previous analyses of observed commercial fisheries data, i.e. that barndoor skate are captured in depths extending to 1000m and beyond. Limited information exists on the reproductive biology of barndoor skate, however recent studies have shown that length at first and 50% maturity is in excess of 105 cm and 110 cm respectively for both male and female barndoor skate. Length composition of barndoor skate from both RV and industry/science surveys show a wide range of sizes, indicative of both juvenile and adult fish. RV surveys appear to capture mainly juveniles. Collectively, the review of these data suggests that barndoor skate is currently sufficiently numerous to ease concerns about its conservation status.

Résumé

On a étudié des données provenant de trois principales sources dans la zone de l'Atlantique canadien, couvrant plusieurs décennies, afin d'établir si la présence de la grande raie y avait été mentionnée. Ces données comprenaient des relevés normalisés et non normalisés de navire de recherche (NR) effectués par le MPO et des relevés récents de l'industrie et du Secteur des sciences. Même s'il y avait plus de 80000 ensembles de données de ces relevés disponibles pour l'analyse, la présence de la grande raie était très peu fréquente (fréquence de 1,26 %). En général, la grande raie était plus commune dans les années 1950 et 1960, comparativement aux décennies suivantes où sa présence a été signalée ici et là au cours des années 1970 et où elle était presque absente pendant les années 1980 jusqu'au début des années 1990. Depuis le milieu des années 1990, les grandes raies sont plus abondantes à la grandeur de la région couvrant le centre et l'ouest de la plate-forme Scotian et le golfe du Maine. Des relevés saisonniers effectués par le NFMS dans les eaux américaines ont corroboré ces observations. Il y avait des endroits où, manifestement, l'espèce est demeurée concentrée, notamment à proximité du Banc Georges et du chenal de Fundy, dans le voisinage du banc de Browns, les eaux centrales et de talus de la plate-forme Scotian et, peut-être, le chenal Laurentien. Les concentrations qui étaient évidentes au début de la série de données mais qui ne le sont plus désormais comprennent la partie orientale de la plate-forme Scotian, la div. 3Ps et les eaux de talus du sud-ouest des Grands bancs. Les relevés de l'industrie et du Secteur des sciences ont fait ressortir que la grande raie était régulièrement capturée à des profondeurs/endroits échappant aux relevés habituels de navire de recherche. Cette observation concorde avec des analyses antérieures de données observées sur la pêche commerciale, c.-à-d. la grande raie est capturée à des profondeurs de 1 000 m et plus. Il y a peu d'information sur la biologie de la reproduction de la grande raie; cependant, des études récentes ont révélé que la longueur à première maturité sexuelle et à maturité à 50 % dépasse respectivement 105 et 110 cm pour les mâles et les femelles. La composition par longueur de la grande raie observée à la fois lors des relevés de NR et des relevés de l'industrie et du Secteur des sciences révèle une grande panoplie de tailles, indicatrice de la présence de juvéniles et d'adultes. Les NR semblent capturer principalement des juvéniles. Collectivement, l'étude de ces données laisse croire que la grande raie est actuellement suffisamment abondante pour que l'état de sa conservation soit moins préoccupant.

Introduction

The barndoor skate (*Dipturus laevis*) is reported to be the largest skate in the northwest Atlantic, growing to about 1.5m in length and 20 kg in weight (Scott and Scott 1988). It is one of a group of closely related species that includes *Dipturus batis* in European waters and *D. floridana* off the southern United States (Bigelow and Schoeder 1953). Its reported range extends from as far north as southwestern Grand Bank and the southern Gulf of St. Lawrence, south to waters off northeastern Florida (Scott and Scott 1988). McEachran and Musick (1975) suggested that the most southerly records may have been a misidentification of *D. floridana* and that *D. laevis* may not occur south of Cape Hatteras. Within this broad geographic range, barndoor skate have been reported from the tide line (and even stranded above it: Bigelow and Schroeder 1953) to depths of 430 m.

Barndoor skate has not been reported as a common species (in survey or commercial catches) nor has it ever been targeted for exploitation. Kulka et al. (1996) first reported that barndoor skate was occasionally taken as by-catch in fisheries prosecuted on the Grand Banks and Labrador Shelf. It was found to be most commonly taken in otter trawl fisheries along the outer edge of the shelf. The closure of many of these fisheries in these offshore areas in the early 1990s has resulted in a lack of information on barndoor skate from these areas. Casey and Myers (1998) brought recent attention to this species in an evaluation of its historical and contemporary status concluding that the species was currently near extinction. Following this publication the U.S. National Marine Fisheries Service was petitioned in 1999 to consider barndoor skate as a candidate for listing under the Endangered Species Act (ESA). Evaluation of the status of barndoor skate in U.S. waters relative to the five listing factors of the ESA led to the conclusion that "there was no evidence that they were in danger of extinction or likely to become endangered within the foreseeable future throughout all or a significant portion of its range." (Northeast Fisheries Science Center 2000).

Information on the distribution, abundance and life history of barndoor skate is very sparse. This is due, in part, to its low catchability. For example, using underwater cameras attached to the head-ropes of standard trawl gear, Edwards (1968) noted that barndoor skate were "extraordinarily adept at avoiding capture". Consequently, this makes any assessment of the conservation status of barndoor skate quite uncertain due to the difficulty of disentangling the effects of catchability from true or human-induced rarity.

The document presented here represents a comprehensive examination of all DFO surveys that might provide information on the occurrence of barndoor skate in the broad geographic area between Georges Bank and northern Labrador (Figure 1). In Canadian waters, barndoor skate have never been a directed species in a commercial fishery. There are, however, directed fisheries for winter skate on the eastern Scotian Shelf (Simon and Frank 1998) and for thorny skate on the Newfoundland shelf (Kulka and Mowbray 1998). Barndoor skate have been reported as by-catch in both domestic and foreign fisheries, monitored by the International Observer Program (IOP) using trained observers, and D. Kulka has compiled and reviewed this information (Kulka et al. 2002).

One might think that the commercial fishery itself would provide information on the occurrence of barndoor skate. Unfortunately, the reporting requirements do not require a separation by species and our commercial fisheries database includes only "skate unspecified".

The data reviewed was derived from three principal sources: i) seasonal research vessel (RV) surveys conducted by DFO that have been in existence for decades using standard sampling protocols, ii) non-standard research vessel surveys, conducted prior to 1970, that preceded the standardized surveys, and iii) industry/science surveys that began in the mid-1990s using either fixed or mobile gear. This latter data source comes mainly from surveys organized by the Marine Fish Division, Maritimes Region.

Generally, the data is composed of number or weight caught, latitude and longitude, depth of capture, time of day, and gear type. More detailed information such as individual length, weight, and sex are available from a subset of the surveys. All of the data is both tabulated and portrayed geographically in order to show the distributional patterns of the species.

Methods

Nine different data sources, including both non-standard and standardized RV surveys, were examined for the presence of barndoor skate (Table 1). These surveys cover virtually all of the Canadian continental shelf waters as well as the Gulf of St. Lawrence. The northern Gulf survey in Div. 3Pn4RS, which is not listed in Table 1, has no record of barndoor skate and its species code does not exist in the survey database. The longest series comes from the Newfoundland region, which has run uninterrupted since 1950. Other surveys, notable for their duration, include those from the Scotian Shelf and southern Gulf of St. Lawrence that commenced in 1970 and 1971 respectively.

An additional five industry/science surveys were also evaluated (Table 2). These surveys are relatively new and are not widely accessible. We have restricted our analysis of such surveys to those organized by the Marine Fish Division, Maritimes region. These surveys have a standard sampling design, the industry participants have undergone training for sampling methods and species identification and in addition, trained observers have been deployed on a majority of the participating vessels.

Details for each of the individual survey series, in terms of location, gear type, time of year, duration and sampling effort, are given in Table 3.

Results

Overall

A total of 80,427 sets were examined for the occurrence of barndoor skate. This represents the total effort from the DFO RV and Industry surveys. Out of this total, barndoor skate occurred in 1015 sets which equates to 1.26% (Table 3).

DFO RV Surveys
On a per survey basis, the 1958-1969 non-standard otter trawl survey yielded the highest percent occurrence of barndoor skate of 11.2%. This was followed by the recent (1986-2001) Georges Bank survey (5Z) with 6.4% and the Subarea 234 (Newfoundland) survey in the 1950s of 4.3% (Table 3). All other surveys yielded relatively low occurrences of barndoor skate.

Industry/DFO Science Surveys
The 3NOP4VWX survey, otherwise known as the halibut longline survey, yielded the highest percent occurrence of barndoor skate of 9.5%. All of the other industry surveys generally yielded relatively higher percent occurrences compared to the DFO surveys.

Overview of individual surveys

Non-standard (3OP4VWX5YZ) RV survey, 1958-1969
This series of surveys had wide geographic coverage but most of the sampling effort was restricted to the central and western Scotian Shelf, where barndoor skate were captured with relatively high frequency during most years (Tables 4 and 5). For example, in Div. 4W greater than 20% of the sets contained barndoor skate in 1959, 1962 and 1964, and was less than 9% in only four out of twelve years (Figure 2). In Div. 4X, percent occurrence exceeded 9% in seven out of nine years (Figure 2). Percent occurrence was generally low in Divs. 4Vn and 4Vs however sampling effort was lower in these areas compared to Divs. 4W and 4X. Sampling effort was lowest and most variable in Divs. 3O, 3P, 4T, 5Y and 5Z (Table 4, Figure 2).

Mean number per tow by geographic area was calculated from each of the annual surveys regardless of the variable sampling effort and lack of sampling design (Table 6). While this information is difficult to interpret it may be useful for comparison with abundance estimates from later RV series (Figure 3).

Information on the size composition of barndoor skate by sex was available for a subset of the surveys. Sizes ranged from 48-146cm for females and 32-152cm for males. There was no clear evidence of distinct modes in the size composition of either sex (Figure 4).

Barndoor skate were distributed across the Scotian Shelf with the highest concentrations occurring on the central Scotian Shelf. Somewhat lesser concentrations were evident on the western Shelf (Figure 5). The distributional patterns for each survey are depicted in Appendix 1.

Summer Survey of the Scotian Shelf
The summer survey is the longest running survey series in the Maritimes region. It began in 1970 and has been conducted every year in July. Out of the 5402 sets completed during 1970-2001 only 45 contained barndoor or 0.8%. To put this figure into perspective relative to other cohabiting species on the Scotian Shelf, the frequency of occurrence of the top 5 species during 1970-92 as presented in Table 3 of Simon and Comeau (1994) was 74% (cod), 70% (American plaice), 65% (thorny skate), 61%

(haddock) and 45% (silver hake). If we look at some similar sized species (i.e. large body) such as Atlantic halibut, winter skate and cusk their frequency of occurrence ranged from 14 – 16% (Simon and Comeau 1994). Clearly, barndoor skate is a relatively rare occurrence in these surveys.

The composite distribution pattern revealed a few areas of concentration, notably the western Scotian Shelf and the Gully (Figure 6). The distributional data was decomposed into four year time blocks showing the persistence of the western Scotian Shelf concentration and the sporadic occurrence of barndoor skate elsewhere (Figures 7 and 8). During 1978-1981 some large sets of barndoor skate were recorded near the Gully on the eastern Scotian Shelf and in Div. 4X (Figure 7). From 1982 to 1993 barndoor skate were infrequently encountered on the shelf. Since 1994, barndoor skate have been present in the vicinity of Browns Bank and the Fundian Channel (Figure 8).

The time series of population numbers (calculated as the product of the stratified mean numbers per tow and the number of trawlable units) revealed contrasting patterns between Div. 4X and 4VW. In Div. 4X, barndoor skate population numbers ranged from 0 – 375,000. The peak in population numbers occurred in 1978. Throughout the late 1970s to early 1990s barndoor skate were only captured in two years. Since 1993, barndoor skate have been captured in every year of the survey and the current population is close to 200,000 (Figure 9). In Div. 4VW, barndoor skate have not been captured since 1980 and the peak estimate of population numbers (>1,000,000) occurred in 1978 (Figure 9).

Composite length frequencies in both Div. 4X and 4VW revealed a broad size range (19-135cm) with some evidence of polymodality (Figure 10). In both geographic areas few barndoor skate in excess of 110cm were captured. This is noteworthy given that recent research conducted on barndoor skate in the vicinity of Closed area II on Georges Bank by T. Gedamke (pers. comm., Virginia Institute of Marine Sciences). In total over 1500 individuals were evaluated for maturity status, however only 40 mature specimens were among the collections. The smallest mature female observed was 113cm TL and the calculated 50% maturity was 116cm. For males, first maturity was observed at 109cm with 50% maturity occurring at 112cm. In recent collections of barndoor on the Scotian Shelf no females below 110cm were found to be mature (Figure 11), but this was based on a relatively small sample size (n = 25). Collectively, this information indicates that barndoor skate do not reach sexual maturity until a relative late age (an assumption) at a body size well above 100cm (a fact). This information leads to the conclusion that recent trawl surveys captured only juvenile barndoor skate in significant quantities while adults were rarely captured. The abundance time series may better reflect some measure of recruitment variation.

A continuous time series was constructed for the standard and non-standard trawl surveys for Div. 4VW and 4X (Figure 12), acknowledging the dissimilarity in the estimation of the mean numbers per tow between them, i.e. standard series is a stratified mean and the other is not. The data show that barndoor skate abundance was 2-3 fold higher, on average, during the late 1950s / mid-1960s compared to the most recent estimates

available in Div. 4X. In Div. 4VW, barndoor skate have not been captured since 1980 (Figure 12).

Spring Survey of the Scotian Shelf
This survey has generally been conducted in March each year from 1979 to present. Until 1984 the survey covered the entire Scotian Shelf. A total of 837 sets were completed during this time and barndoor skate were present in two sets (or 0.2%). This information is presented in Figure 13. Since 1986 the survey has been restricted to the eastern half of the shelf and 1256 sets were completed. Barndoor skate occurred in only one set for a percent occurrence of 0.1%. Figure 14 shows the set locations associated with this survey.

Fall Survey of the Scotian Shelf
This survey was restricted to the time period 1978-86 and 1042 sets were completed. Barndoor skate were only caught at two locations (Figure 15). This is consistent with the general absence of barndoor skate from the Scotian Shelf during the 1980s (Figure 9).

Winter Survey of Georges Bank
The Georges Bank survey began in 1984 when a partial survey of the bank was conducted. In 1986 the survey was expanded to cover the entire bank and the geographic scope of the survey has remained unchanged to present. A total of 1464 sets have been completed since 1986 with 94 or 6.4% containing barndoor skate. Barndoor skate were distributed along the southern flank of Georges Bank from the Northeast Peak to the Great Southwest Channel (Figure 16). Relatively high concentrations were seen during 1998-2001 along the Southern Flank of the bank (Figure 17).

The population estimates of barndoor skate have been steadily increasing since the early 1990s with a peak of more than 750,000 in 1998 (Figure 18). It is also notable that barndoor skate have been present in every year of the survey since its inception (Figure 18). A broad range of sizes of barndoor skate have been encountered on Georges Bank, ranging from 15 to 125 cm, with the vast majority of individuals less than 100 cm (Figure 19).

Gulf of St. Lawrence
Two seasonal surveys have been conducted in this region, one during the winter and the other in early fall. The winter survey captured barndoor skate in four sets out of 400 completed during 1995-1998. The fall survey captured barndoor skate in two out of 4134 sets since 1971. The few barndoor skate captured during these surveys were located in the deep waters of Cabot Strait (Figure 20) and the slope waters of the Laurentian Channel (Figure 21).

Newfoundland Subarea 234 surveys
This was the most extensive survey available for analysis in terms of duration and geographic scope. Similar to the surveys on the Scotian Shelf, the earlier years in the series (pre-1970) were not associated with any particular survey design. However, a random stratified survey design was adopted in 1970, 1971 and 1978 in Div. 3LNO, 3P,

and 2J3K respectively. A total of 56,110 sets were completed from 1947-1999 with barndoor skate occurring in 289 or 0.5%. The percent occurrence during 1947-1970 was relatively high (270 sets with barndoor skate out of 9888 or 2.7%) due, in part, to the inclusion of the Scotian Shelf in the surveys for those years.

The composite distribution based on the entire survey series shows concentrations of barndoor skate on the central Scotian Shelf, along the slope waters of the Shelf, along the southwestern slope of the Grand Banks extending into the Laurentian Channel and into Div. 3Ps. Minor concentrations occurred on the Southeast Shoal, on the eastern Scotian Shelf and in the vicinity of Flemish Pass (Figure 22). Decomposing the data into ten year time blocks revealed the persistence of the major concentrations during the twenty-five years of surveys prior to 1970 on the Scotian Shelf (Figures 23, 24 and 25). The concentrations in 3Ps, the Laurentian Channel and the southwestern slope waters of the Grand Banks were also evident during this period. The concentration on the Southeast Shoal was only evident during 1951-1960 (Figure 24). The post-1970 period revealed a loss of concentrations in the 3Ps/Laurentian Channel region as well as the southwestern slope waters of the Grand Banks (Figure 26, 27 and 28). Barndoor skate were captured sporadically throughout the remainder of the survey area although a minor concentration was evident during 1991-1999 in the Flemish Pass area.

Industry/Science Surveys

Monkfish Survey (Div. 4X/5Z Otter trawl)
This survey ran from 1995-1999 and was conducted each year in October by five industry trawlers equipped with rockhopper footgear. A total of 1002 sets were completed with barndoor skate occurring in 33 or 3.3%. Barndoor skate were encountered on Georges Bank and the eastern half of the survey area (Figure 29). Barndoor skate also occurred as by catch in the commercial index phase of this survey, with concentrations associated with the edges of the Fundian Channel. Barndoor skate abundance, in terms of weight per tow, is presented in Figure 30.

ITQ Survey of the southwestern Scotian Shelf (Div. 4X Otter trawl)
This survey has been conducted each July since 1995 using four industry trawlers equipped with rockhopper foot gear. A total of 1275 sets have been completed with barndoor skate occurring in 30 or 2.4%. Barndoor skate were generally captured in the deep waters off German and Browns Bank (Figure 31). Perusal of each annual survey revealed an increasing occurrence of barndoor skate as well as some consistent areas of capture such as the deep waters around Browns and German Bank (Figure 32). Abundance, in terms of weight per tow, has exhibited an increasing trend (Figure 33).

Sentinel Survey of the eastern Scotian Shelf (Div. 4VsW Longline)
The sentinel survey began in September of 1995 and has continued to present. No skates were identified to species during the 1995 survey. This situation changed in 1996 after additional training was completed by the industry participants. A total of 1548 sets have been completed since 1996 with 5% (or 77 sets) having barndoor skate present.

Barndoor skate catches were concentrated along the western boundary of the survey area (or central Scotian Shelf) between Emerald Basin and Emerald Bank and southward to the edge of the shelf (Figure 34). Unlike the previous surveys reviewed, this survey used longline gear. Examination of each of the annual surveys revealed that barndoor skate were consistently captured in a broad, cross-shelf band along the central Scotian Shelf (Figures 35 and 36). For completeness sake, the distribution of barndoor skate from the commercial index phase of the sentinel survey is also shown (Figure 37).

There was no apparent trend in the abundance of barndoor skate, although the survey series is relatively short. Estimates of weight per tow were 2-4-fold higher relative to the previous industry/science surveys reviewed thus far (Figure 38).

Length measurements were not made on regular basis from each survey, instead they were made only infrequently when time permitted. This resulted in a relatively small, possibly biased, sub-sample to characterize a relatively large concentration of barndoor skate. Length ranged from 82-136cm (Figure 39).

Halibut Survey and Index Fishery (Div. 3NOP4VWX Longline)
In the summer of 1998 the first industry survey of halibut was initiated. Like the sentinel survey, longline gear was used. A total of 780 sets have been completed with barndoor skate occurring in 74 or 9.5%. This survey yielded the highest incidence of barndoor skate, based on presence/absence, among the industry/science surveys reviewed.

During 1998-2001, barndoor skate were captured mainly on the central Scotian Shelf and in the vicinity of Browns Bank with a lesser concentration associated with the Laurentian Channel area (Figure 40). Examination of each of the annual surveys revealed persistent concentrations on the central Scotian Shelf and in the vicinity of Browns Bank (Figure 41). Other areas where barndoor skate were captured included the edges of the Scotian Shelf and the Laurentian Channel. There were no barndoor skate captured in the southwestern Grand Banks region (Figure 41). Number and weight per set appear to have been increasing since the beginning of the survey in 1998 (Figure 42).

The halibut index fishery in 1998 was located along the slope waters of the Scotian Shelf and into the Gully. Monitoring of the fishery by DFO observers revealed that barndoor skate were taken as by-catch (total of 3000 kg) in the vicinity south of Emerald Bank, the southeast portion of Browns Bank, and northeast slope waters off Banquereau Bank (Figure 43). Very few barndoor skate were encountered in other areas.

Both the survey and index fishery also provided information on depth distribution of barndoor skate, with set locations distributed from 50 to 950m. Number per set was at a maximum in the 100-250m depth range. Barndoor skate were also captured at depths ranging from 350 to 850m (Figure 44).

4VsW Skate survey
This otter trawl survey began in 1995 and has completed 1110 sets with barndoor skate occurring in 8 sets or 0.7%. The principal target of this survey was winter skate and the

survey was considered adequate for this species. The catches of barndoor skate were low and confined to Banquereau Bank and adjacent slope waters (Figure 45).

Discussion/Conclusions

Barndoor skates were relatively more common in the 1950s and 1960s in comparison to later decades when they were sporadically encountered throughout the 1970s, nearly absent during the 1980s, and increased in abundance since the mid-1990s throughout the central/western Scotian Shelf/Gulf of Maine area. It should be noted that research vessel trawl surveys on Georges Bank, conducted by NMFS, have shown similar recent increases in barndoor skate abundance from both spring and fall surveys (Northeast Fisheries Science Center 2000).

There appear to be some persistent areas of concentration, i.e. those associated with Georges Bank/Fundian Channel region, in the vicinity of Browns Bank, the central and slope waters of the Scotian Shelf and possibly the Laurentian Channel region. Concentrations that were evident early in data series but are not evident now include the eastern Scotian Shelf, Div. 3Ps and the southwestern slope waters of the Grand Banks.

It was apparent from the industry/science surveys that barndoor skate were consistently captured at depths/locations beyond the standard research vessel surveys. This observation is in agreement with previous analyses of observed commercial fisheries data, i.e. that barndoor skate are captured in deep water extending to depths of 1000m and beyond (Kulka et al.1996).

Recent sampling of barndoor skate has revealed that the length at first and 50% maturity is in excess of 105cm and 110cm respectively for both male and female barndoor skate. This is the first such evidence of size at maturity for barndoor skate and it is significant because length frequency data from the RV surveys indicated that most individuals captured are immature. Length composition of barndoor skate from industry/science surveys revealed a wide range of sizes, indicative of both juvenile and adult fish.

Collectively, the review of these data suggests that barndoor skate is currently sufficiently numerous to ease concerns about its conservation status.

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Table 1. Temporal and spatial extent of data used in examining the distribution and abundance of barndoor skate in Canadian waters from DFO research vessels surveys. OT-otter trawl, Various-all gears combined

	Research Vessel Surveys								
Area	Gulf 5P4V	Georges 5Z	Spring 4VWX	Spring 4VsW	Summer 4VWX	Gulf 4T	Fall 4VWX	pre 70's 3OP4VWX5Z	Nfld Subareas 234
Month	Jan.	Feb/Mar	Mar	Mar	July	Sept	Oct/Nov	Jan-Dec	Jan-Dec
Gear	OT	OT	OT	OT	OT	OT	OT	OT	Various
Year									
1947									X
1948									X
1949									
1950									X
1951									X
1952									X
1953									X
1954									X
1955									X
1956									X
1957									X
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1974					X	X			X
1975					X	X			X
1976					X	X			X
1977					X	X			X
1978					X	X	X		X
1979			X		X	X	X		X
1980			X		X	X	X		X
1981			X		X	X	X		X
1982			X		X	X	X		X
1983			X		X	X	X		X
1984		X	X		X	X	X		X
1985			X		X	X			X
1986		X		X	X	X	X		X
1987		X		X	X	X			X
1988		X		X	X	X			X
1989		X		X	X	X			X
1990		X		X	X	X			X
1991		X		X	X	X			X
1992		X		X	X	X			X
1993		X		X	X	X			X
1994	X	X		X	X	X			X
1995	X	X		X	X	X			X
1996	X	X		X	X	X			X
1997	X	X		X	X	X			X
1998		X			X	X			X
1999		X		X	X	X			X
2000		X		X	X	X			X
2001		X		X	X	X			

Table 2. Temporal and spatial extent of data used in examining the distribution and abundance of barndoor skate in Canadian waters from industry/science surveys.
OT- otter trawl, LL-longline

	Industry Surveys				
	ITQ 4X Summer OT	Monkfish 4WX5Z Fall OT	Sentinel 4VsW Fall LL	Halibut 3PO4VWX June/July LL	Skate 4VsW April/October OT
Year					
1947					
1948					
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1992					
1993					
1994					
1995	X	X			X
1996	X	X	X		X
1997	X	X	X		X
1998	X	X	X	X	X
1999	X	X	X	X	X
2000	X		X	X	X
2001	X		X	X	X

Table 3. Details of the individual survey series from Tables 1&2 showing gear type, season, sampling effort (number of sets) and percent occurance of barndoor skate.

Survey	NAFO Area	Gear Type	Season(month)	Years	Total number of sets	Number of sets with barndoor	Percent occurrence
RV(non-standard)	3OP4VWX5YZ	OT	Jan.-Dec.	1958-1969	2751	307	11.2
RV	3Pns4V	OT	Winter(Jan.)	1995-1998	400	4	1.0
RV	5Z	OT	Winter(Feb.)	1986-2001	1464	94	6.4
RV	4VWX	OT	Spring(Mar.)	1979-1985	837	2	0.2
RV	4VsW	OT	Spring(Mar.)	1986-2001	1256	1	0.1
RV	4VWX	OT	Summer(July)	1970-2001	5402	45	0.8
RV	4TVn	OT	Fall(Sept.)	1971-2001	4134	8	0.2
RV	4VWX	OT	Fall(Oct./Nov.)	1978-84,86	1042	2	0.2
				Sum	17286	463	2.7
RV	Subareas 234	various	All year	1947-1950	837	29	3.5
RV	Subareas 234	various	All year	1951-1960	4275	185	4.3
RV	Subareas 234	various	All year	1961-1970	4776	56	1.2
RV	Subareas 234	various	All year	1971-1980	10480	9	0.1
RV	Subareas 234	various	All year	1981-1990	18987	5	0.0
RV	Subareas 234	various	All year	1991-1999	16755	5	0.0
				Sum	56110	289	0.5
Industry RV	4X	OT	Summer(July)	1995-2001	1275	30	2.4
Industry RV	4X5Z	OT	Fall(Oct.)	1995-1999	1002	33	3.3
Industry RV	4VsW	OT	Spring(Apr.)/Fall(Oct)	1995-2001	1110	8	0.7
				Sum	3387	71	2.1
Industry RV	4VsW	LL	Fall(Sept/Oct)	1996-98	1548	77	5.0
Industry RV	3NOP4VWX	LL	Spring(June)	1998-2001	780	74	9.5
				Sum	2328	151	6.5
Commercial index	3PN4VWX	LL	Spring/Summer (June/July)	1998-2001	1316	41	3.1

Table 4. Comparison of total number of non-standard survey sets vs sets with barndoor by NAFO division from 1958 to 1969.

	3O		3P		4T		4Vn		4Vs	
	Barndoor sets	Total Sets	Barndoor sets	Total Sets	Barndoor sets	Total Sets	Barndoor sets	Total Sets	Barndoor sets	Total Sets
1958									0	1
1959							1	1	8	45
1960					0	31	0	35	0	12
1961					0	2	0	18	0	4
1962	0	1			11	36	0	7	27	61
1963	6	31	4	11	0	15	1	19	0	14
1964							3	62	7	50
1965							0	52	0	28
1966									1	36
1967									0	30
1968							0	1	0	11
1969					0	13	0	35	0	8
Sum	6	32	4	11	11	98	5	229	43	299

	4W		4X		5Y		5Z		Total	Total
	Barndoor sets	Total Sets	Barndoor sets	Total Sets	Barndoor sets	Total Sets	Barndoor sets	Total Sets	Barndoor sets	All Sets
1958	1	76							1	77
1959	43	183							82	309
1960	35	256							35	334
1961	1	89	0	12					1	125
1962	26	119	6	34	2	27	10	31	82	315
1963	2	53	17	117	0	9			30	269
1964	25	113	13	106			2	25	50	356
1965	19	91	27	197			1	11	46	377
1966	9	91	9	54					18	191
1967	8	86	1	11					9	127
1968	9	88	4	60			0	8	13	168
1969	3	109	11	57					14	217
Sum	179	1329	87	648	2	36	13	75	3501	2751

Table 5. Percent occurance of barndoor skate from the non-standard DFO surveys by division.

Year	3O	3P	4T	4Vn	4Vs	4W	4X	5Y	5Z	Total
1958					0	1.32				1.30
1959				100.00	17.78	26.36				24.88
1960			0	0	0	13.67				10.48
1961			0	0	0	1.12	0			0.81
1962	0		31.43	0	44.26	21.85	17.65	7.41	32.26	26.03
1963	19.35	36.36	0	5.26	0	3.77	14.53	0		11.15
1964				4.84	14.00	22.12	12.26		8.00	14.04
1965				0	0	19.78	13.71		9.09	12.20
1966					2.78	9.89	14.81			9.94
1967					0	9.30	9.09			7.09
1968			0	0	0	9.30	6.67		0	7.23
1969			0	0	0	2.94	19.30			6.45

Table 6. Average number per tow of barndoor skate from the non-standard research vessel surveys.

Year	3O	3P	4T	4Vn	4Vs	4W	4X	5Y	5Z	
1958					0.00	0.01				
1959				2.00	0.58	1.00				
1960			0.00	0.00	0.00	0.29				
1961			0.00	0.00	0.00	0.02	0.00			
1962	0.00		0.37	0.00	7.11	0.88	0.32	0.15	1.94	
1963	0.39	0.96	0.00	0.05	0.00	0.13	0.29	0.00		
1964				0.06	0.24	0.36	0.22		0.13	
1965				0.00	0.00	1.06	0.18		0.09	
1966					0.11	0.27	0.76			
1967					0.00	0.37	0.09			
1968				0.00	0.00	0.14	0.08		0.00	
1969			0.00	0.00	0.00	0.04	0.22			

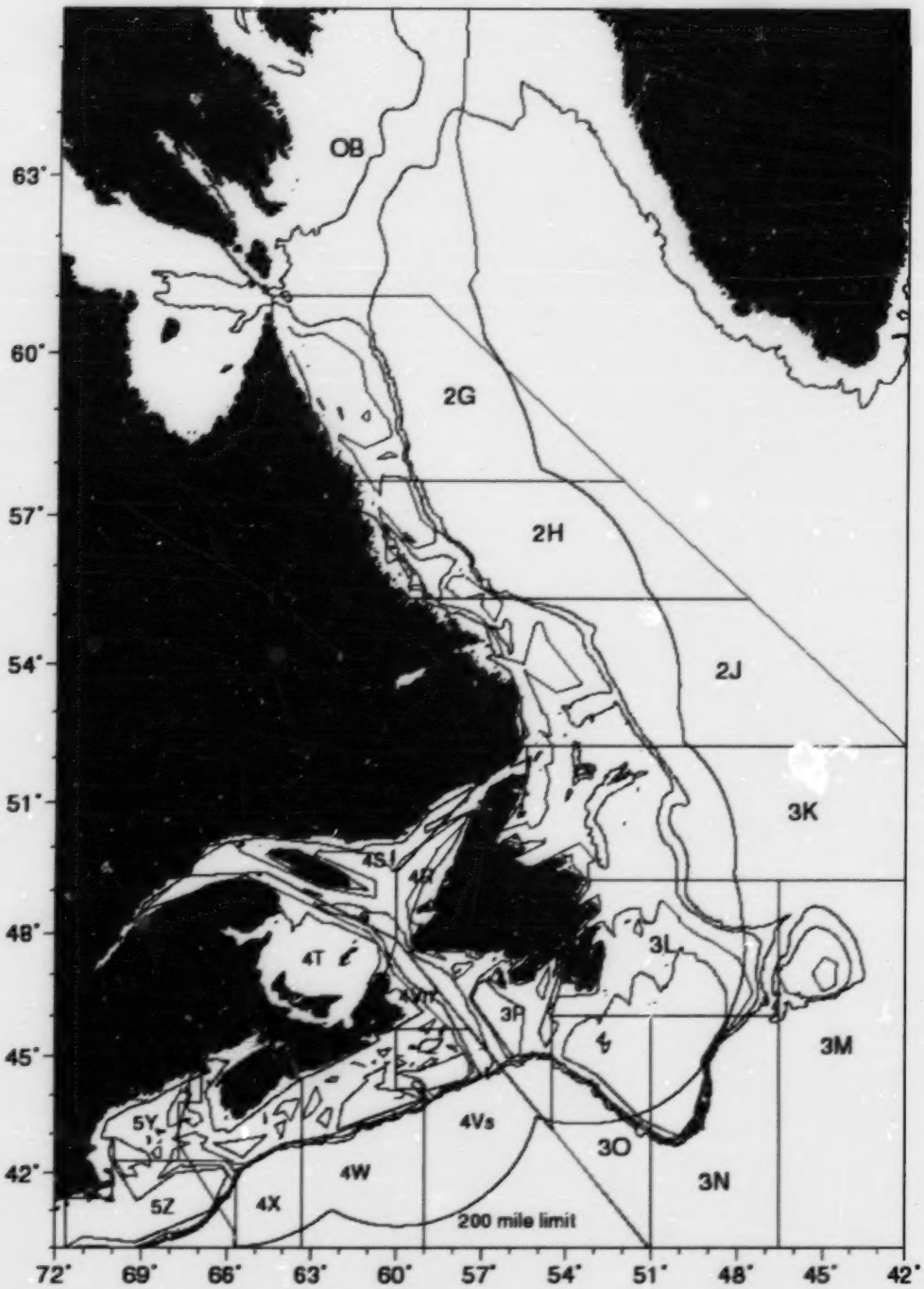


Figure 1. Geographic display of the areas and NAFO divisions mentioned in this document.

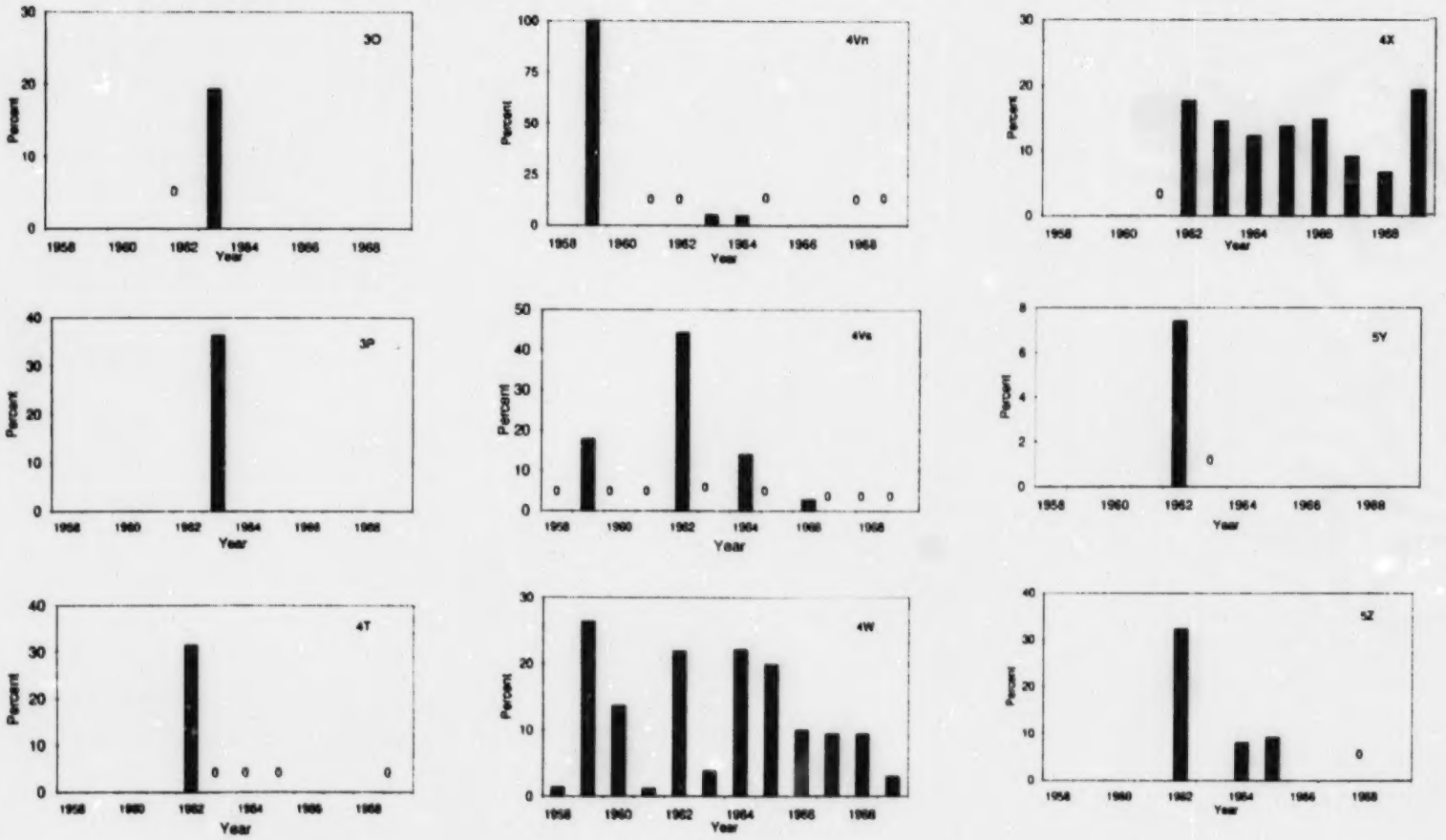


Figure 2 Percentage of sets with barndoor skate from the non standard DFO surveys from 1958 to 1969. Zeros in each plot indicates that there were sets but no catch in those years.

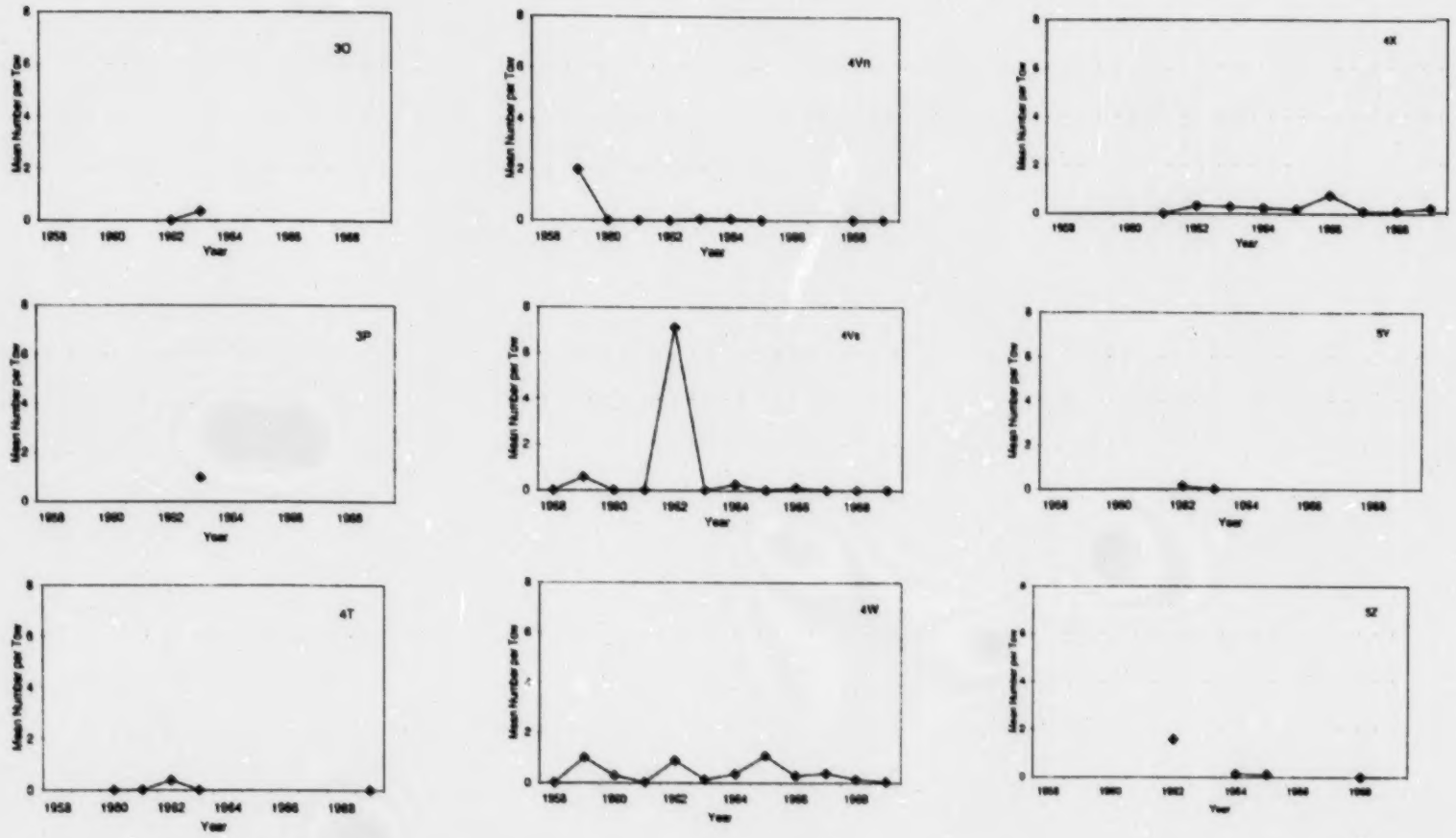
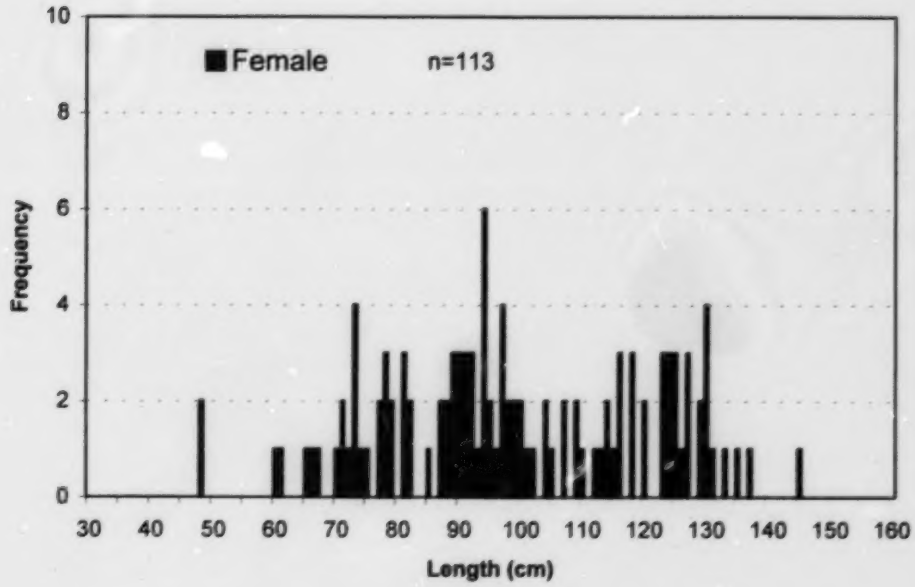


Figure 3 Mean catch per tow of barndoor skate from the non-standard DFO surveys from 1958-1969.



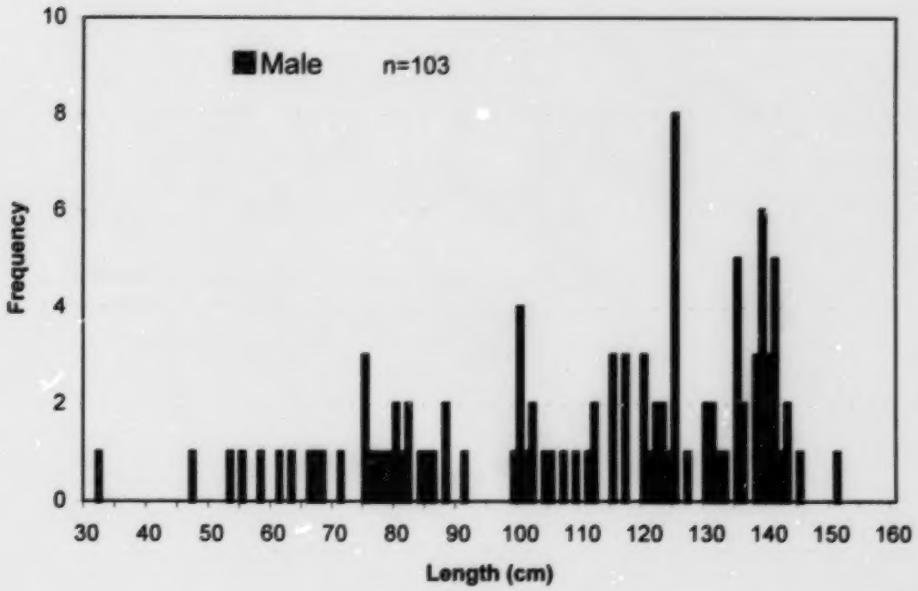


Figure 4. Length frequencies of female and male barndoor skate from the non-standard surveys conducted from 1958-1969.

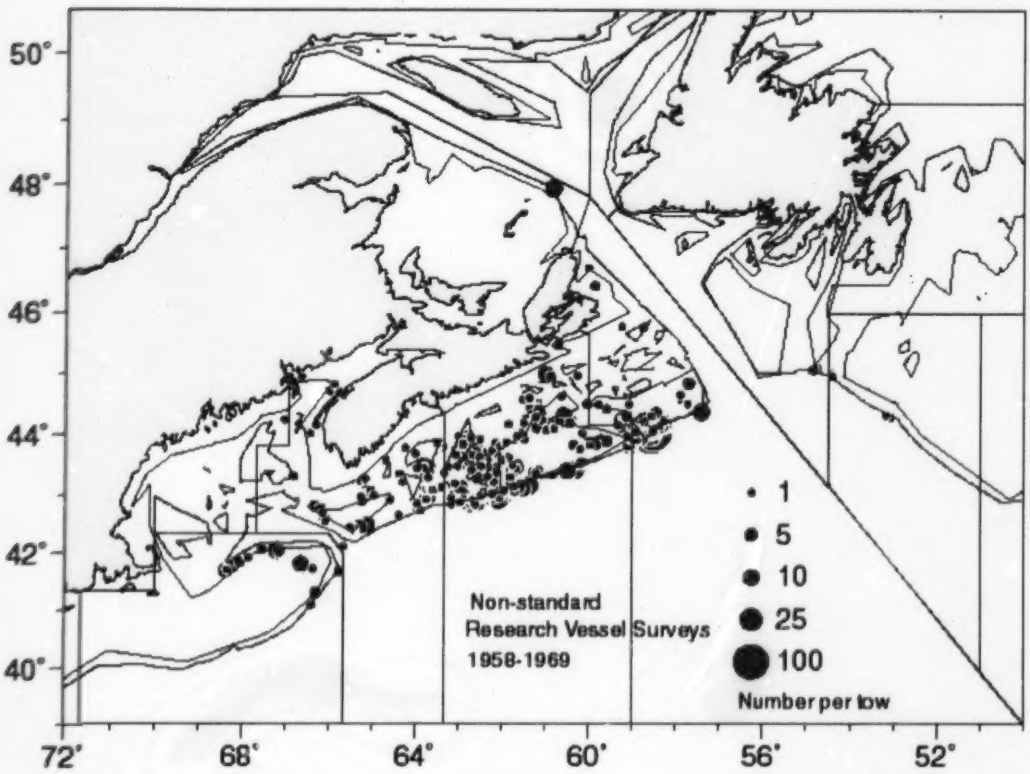


Figure 5. Composite of non-standard research vessel surveys conducted during 1958-1969 showing locations where barndoor skate were present. Note: Location of null sets not shown.

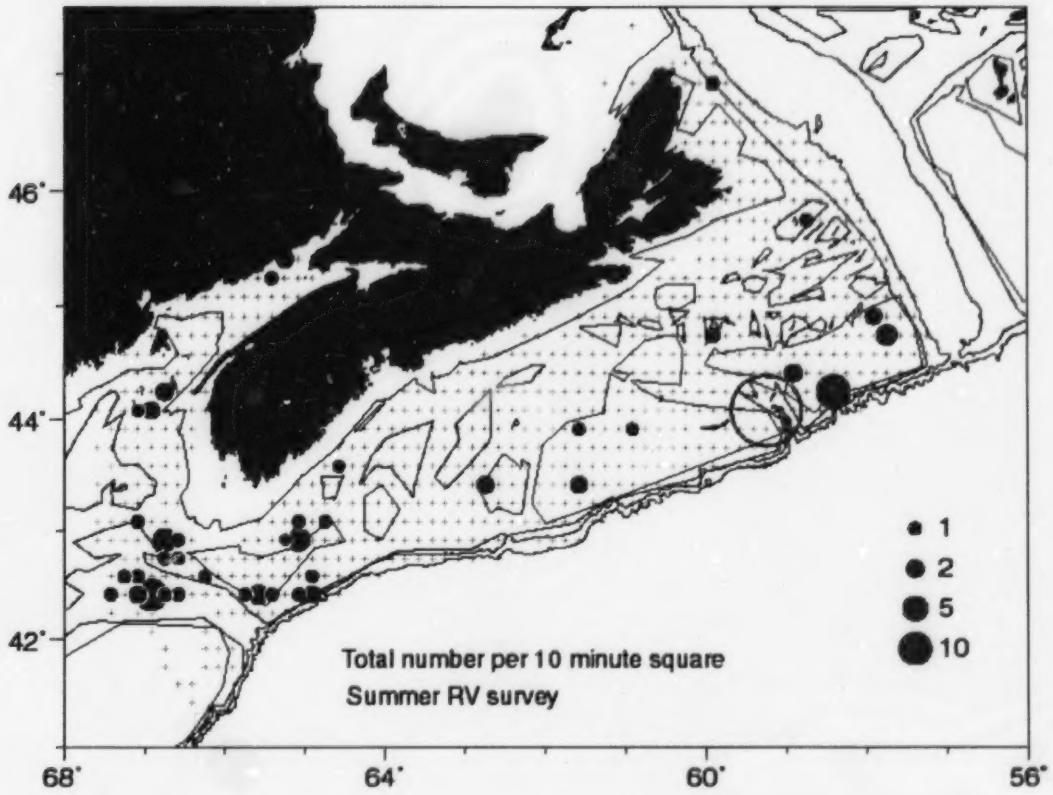


Figure 6. Total number of barndoor skate per 10 minute square from the summer research vessel survey, 1970-2001.

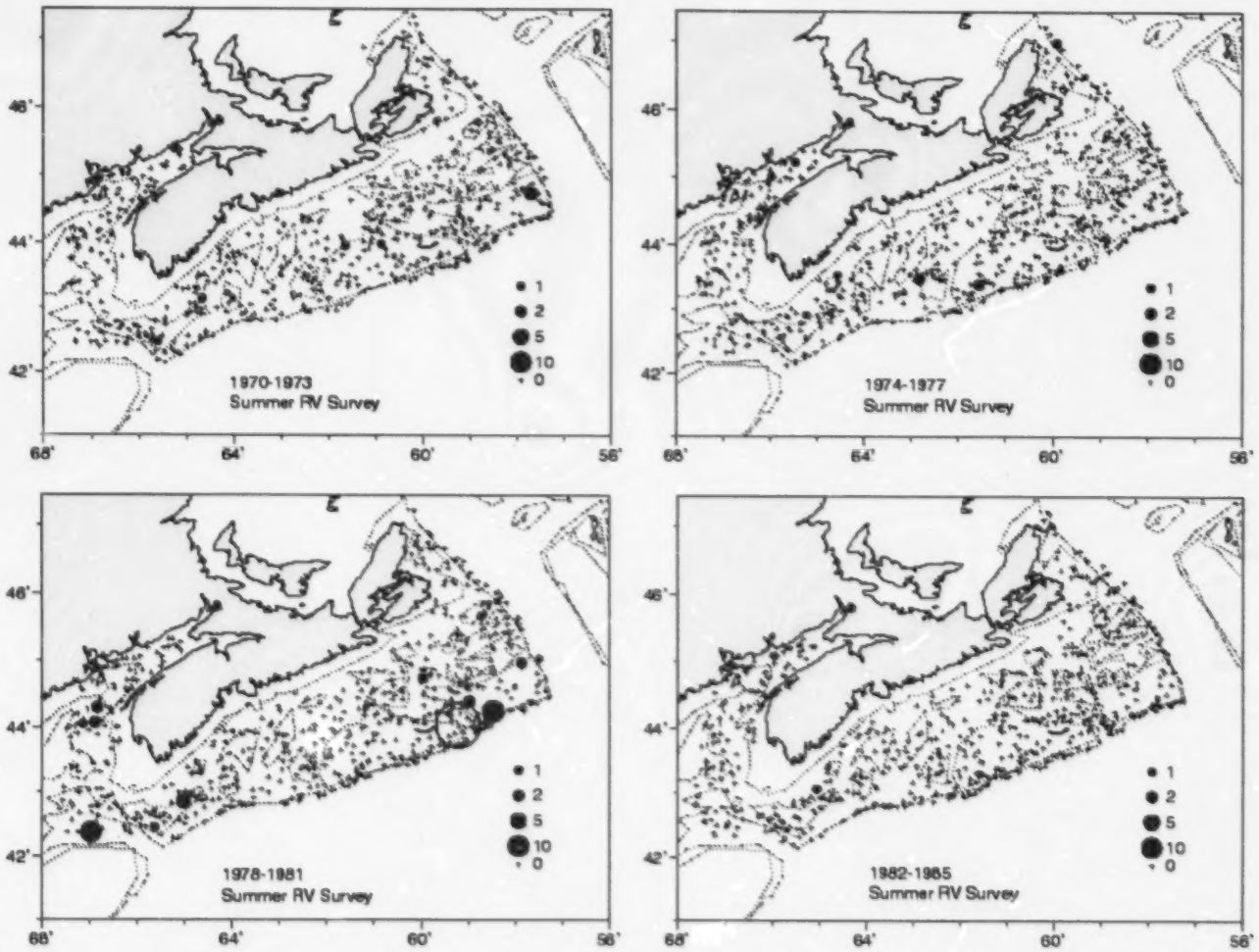


Figure 7 . Number per tow of barndoor skate caught during the summer research vessel survey on the Scotian Shelf aggregated into four year time blocks.

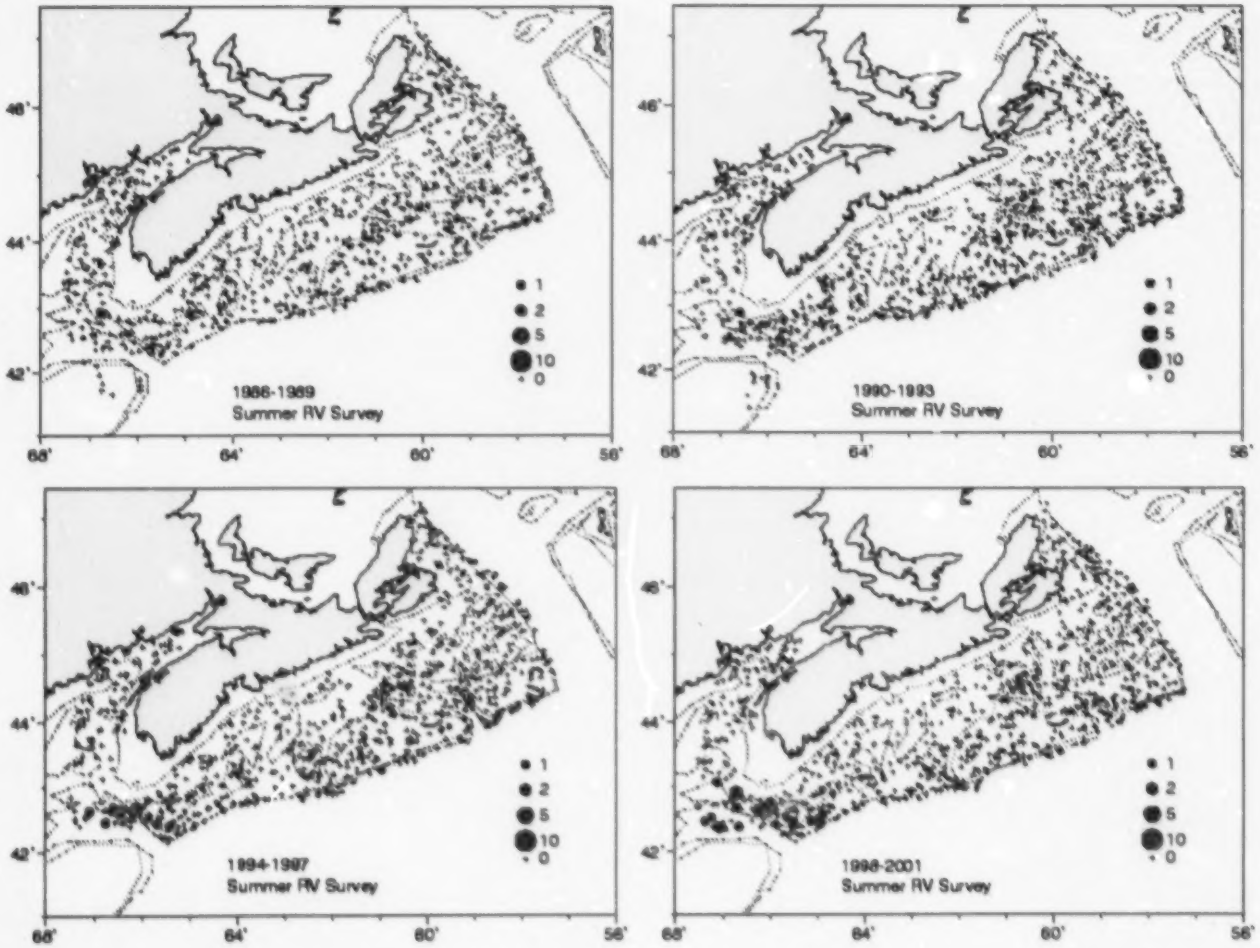


Figure 8. Number per tow of barndoor skate caught during the summer research vessel survey on the Scotain Shelf aggregated into four year time blocks.

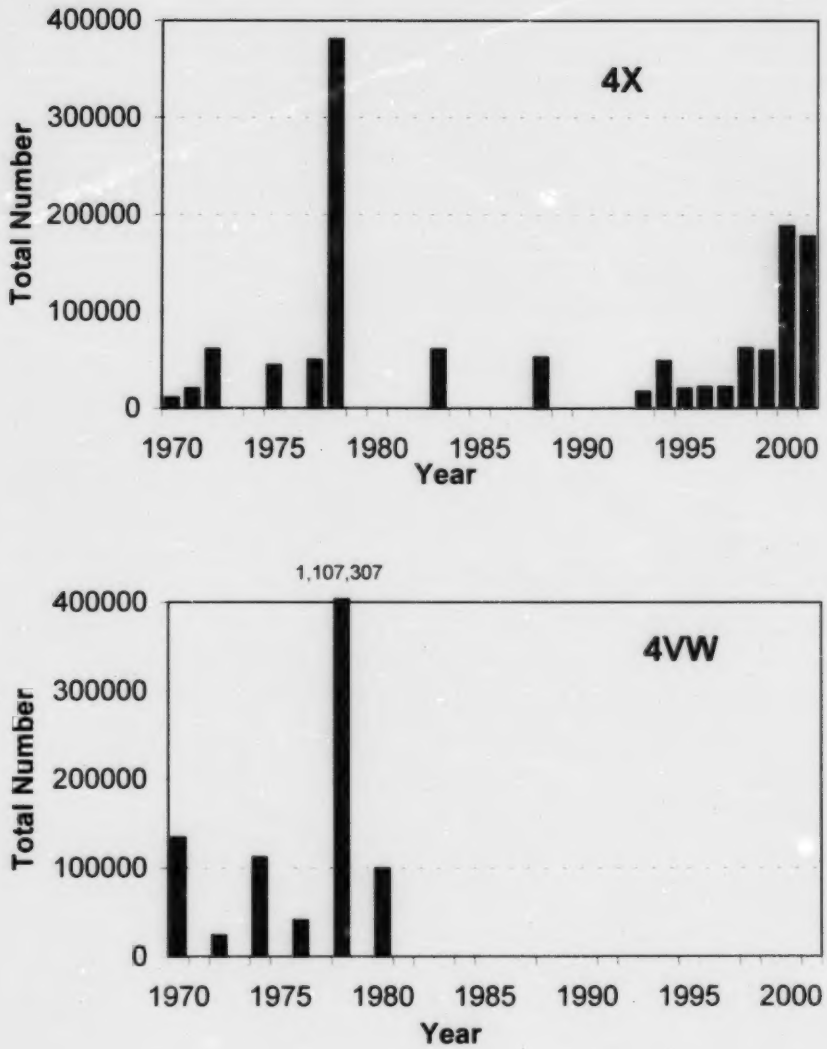


Figure 9. Total number of barndoor skate in Div. 4X and Divs. 4VW as estimated by the summer research vessel survey.

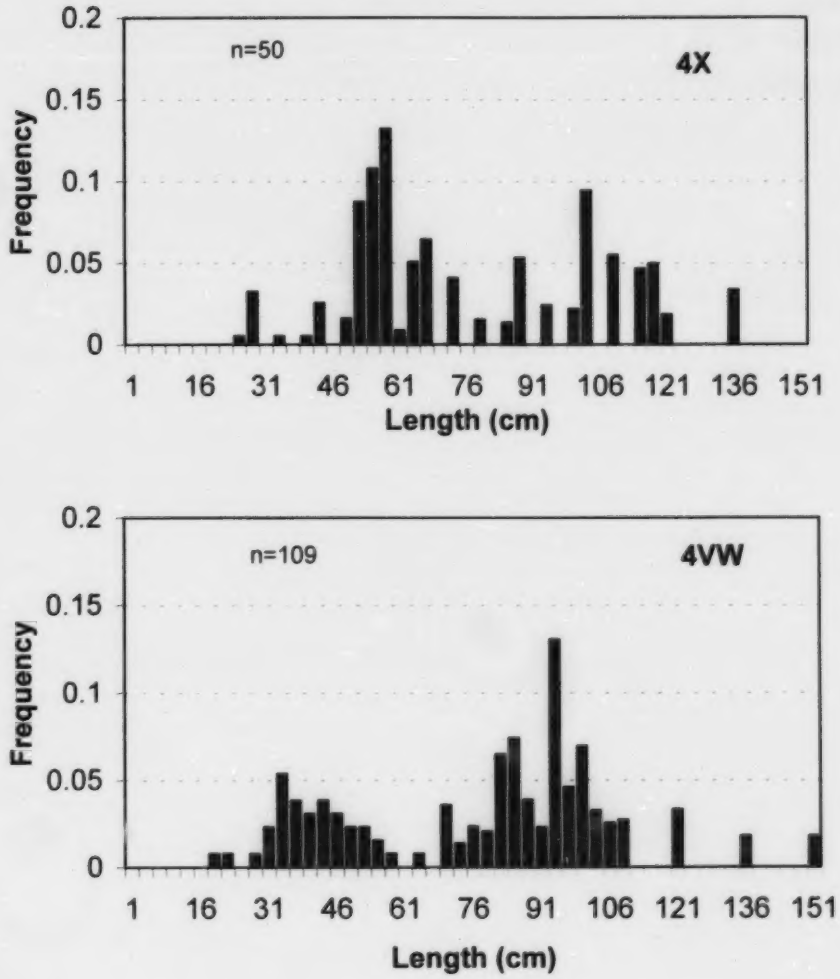


Figure 10. Length frequencies of barndoor skate in Div. 4VW , Div. 4X from the summer research vessel survey.

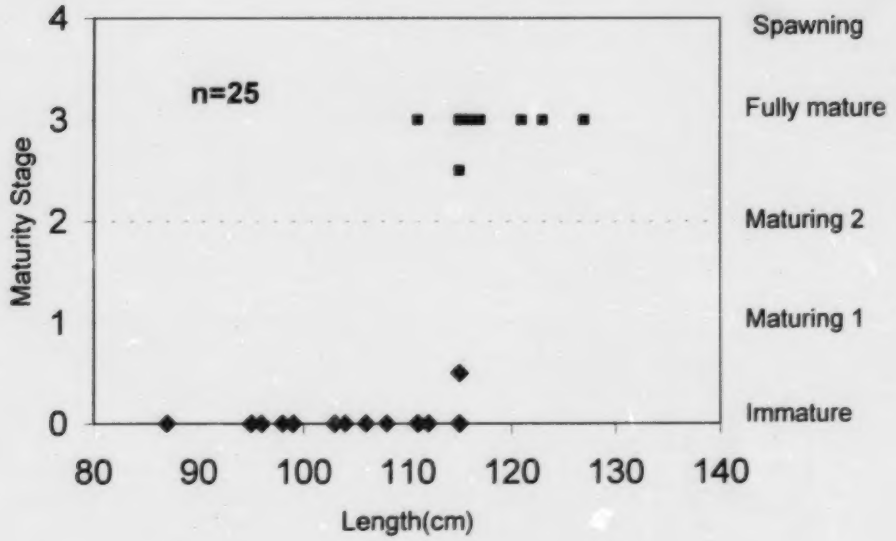
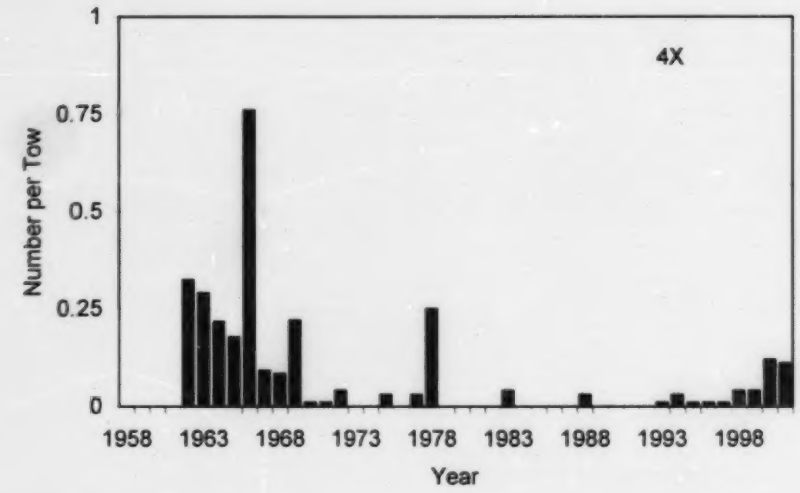


Figure 11. Scatterplot of female barndoor skate from the Div. 4VsW longline Sentinel Survey. Symbols represent the maturity stage assigned to individual fish.



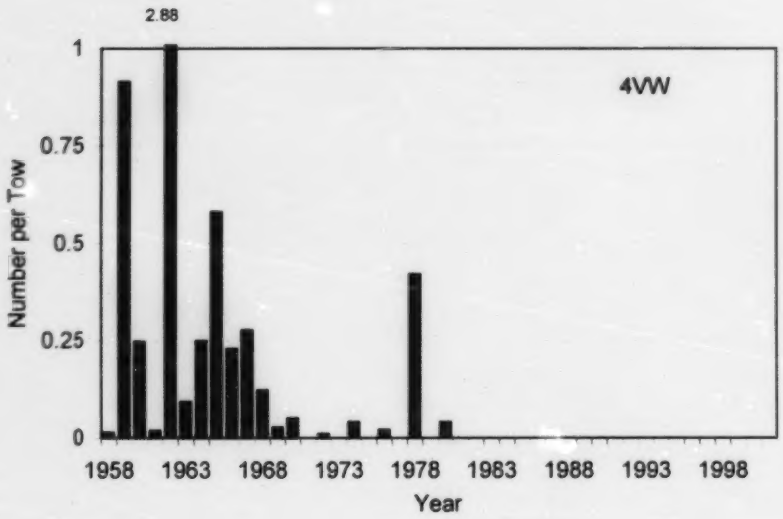


Figure 12. Composite of mean number per tow from the pre 1970's RV surveys and stratified mean number per tow from the summer research vessel surveys in Div. 4VW and Div. 4X of barndoor skate.

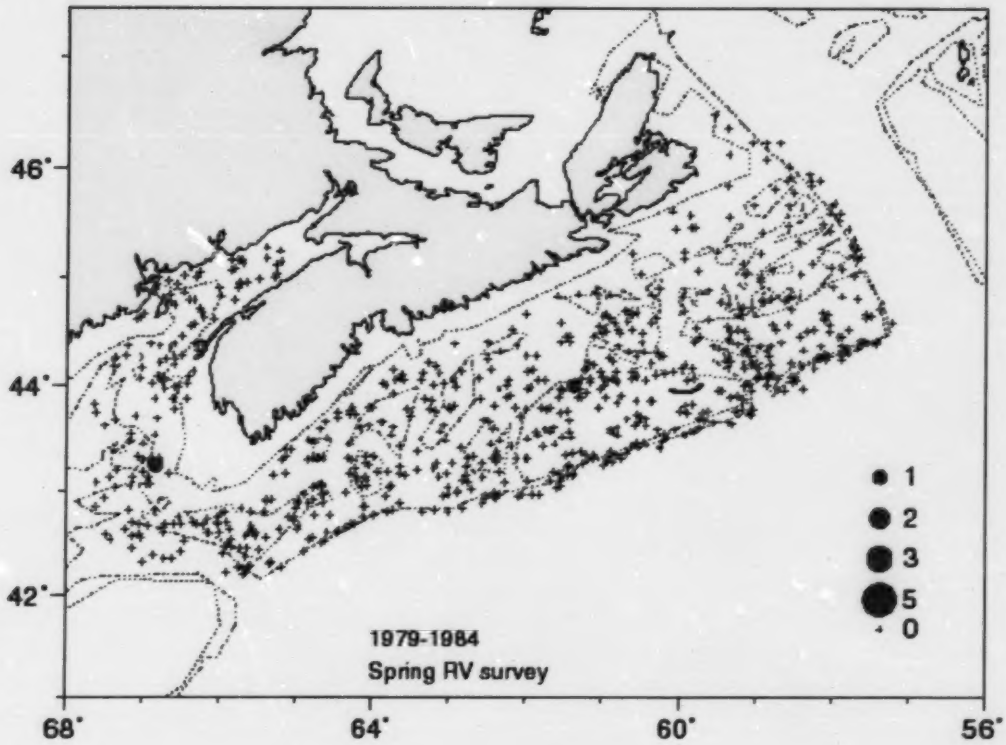


Figure 13. Number per tow of barndoor skate from the spring research vessel survey on the Scotian Shelf, 1979-1984.

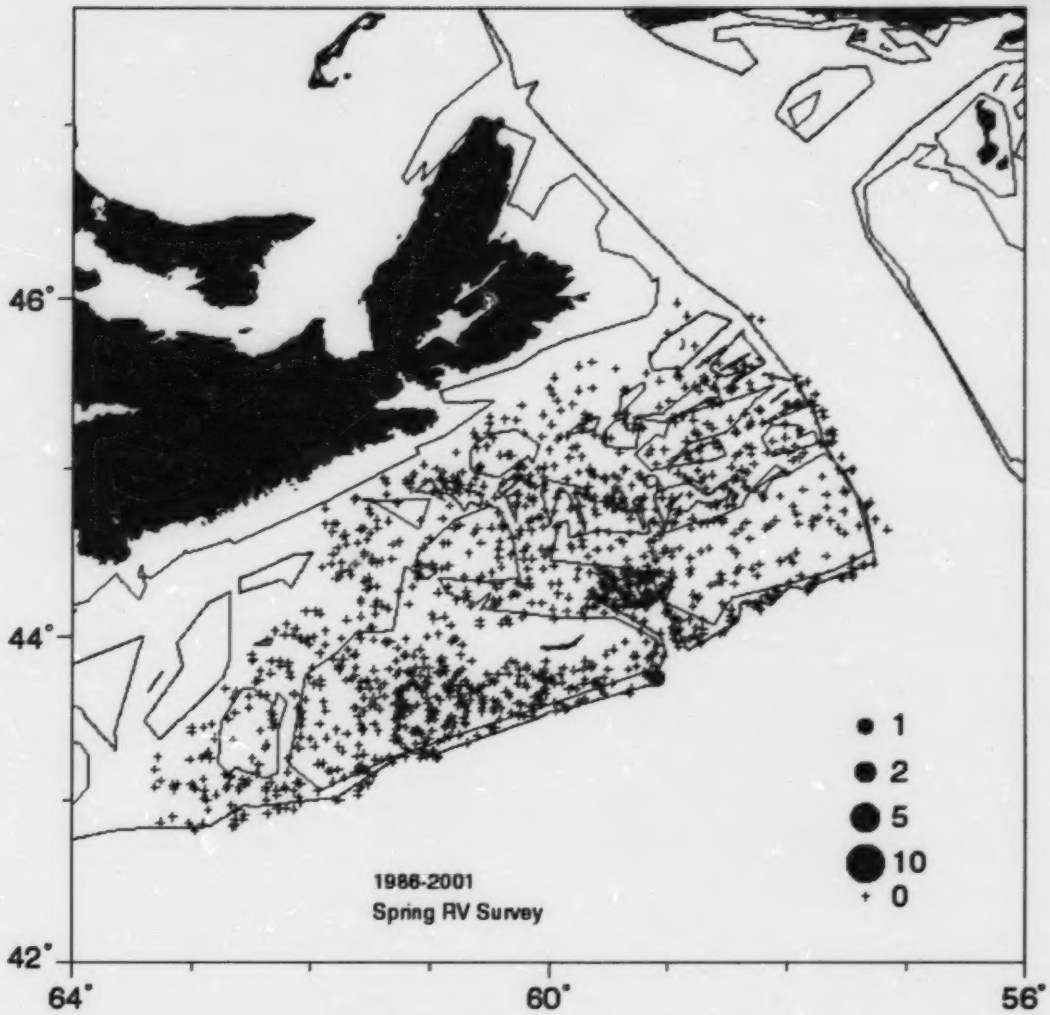


Figure 14. Number per tow of barndoor skate from the spring research vessel survey of the eastern Scotian Shelf, 1986-2001.

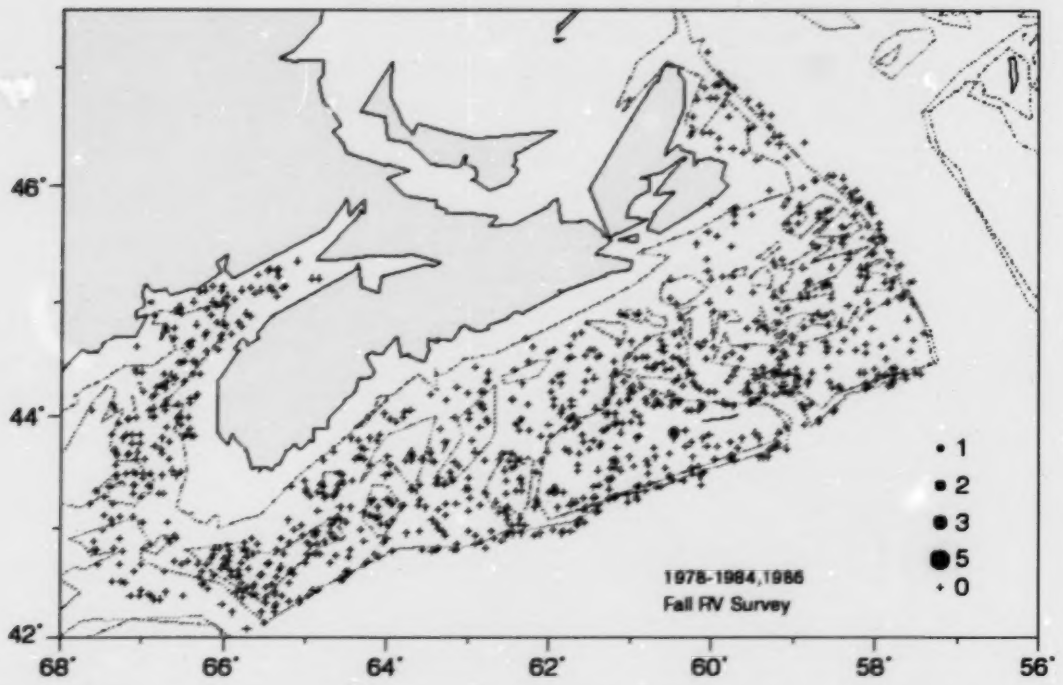


Figure 15. Number per tow of barndoor skate from the fall research vessel survey on the Scotian Shelf, 1978-1984, 1986.

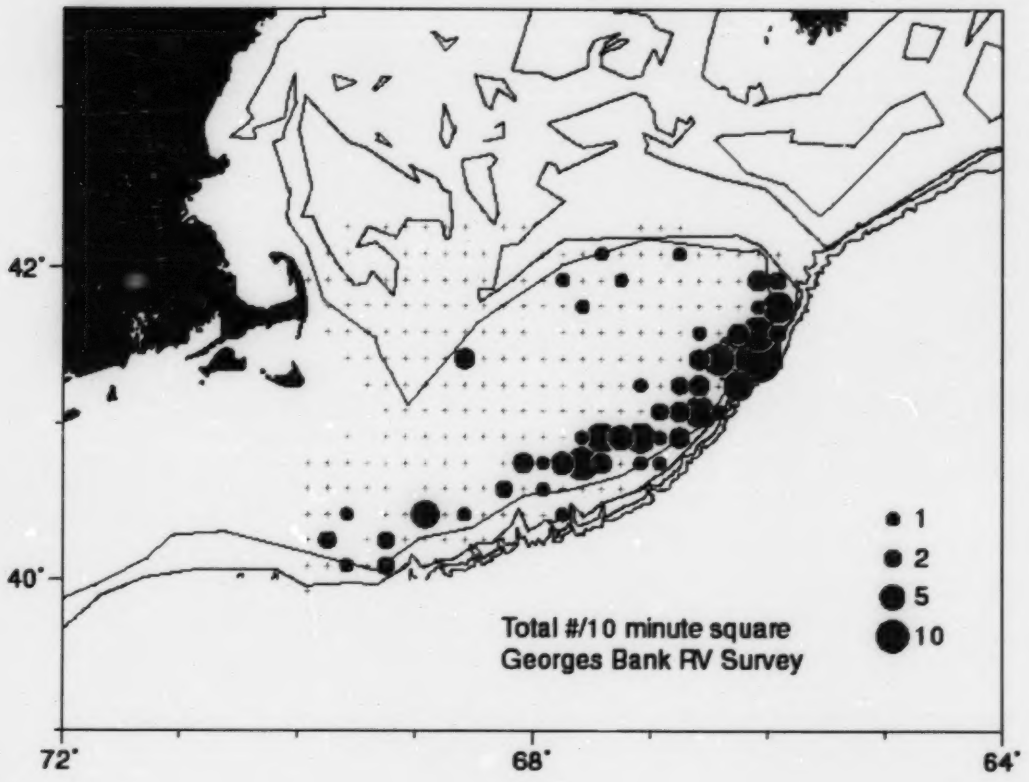


Figure 16. Total number of barndoor skate per 10 minute square from the Georges Bank research vessel survey, 1986-2001.

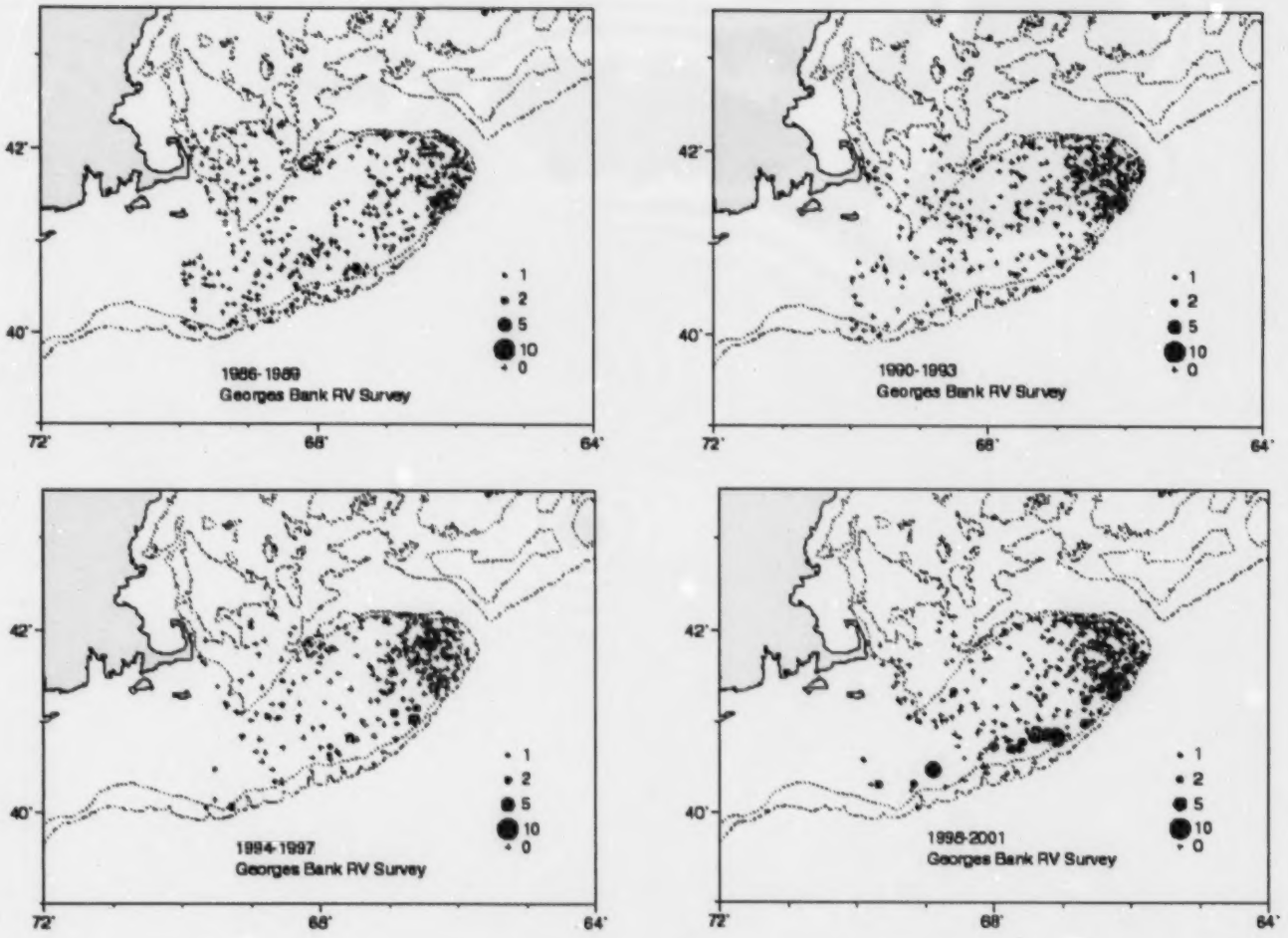


Figure 17. Number per tow of barndoor skate aggregated in four year time blocks for the Georges Bank research survey conducted in February each year.

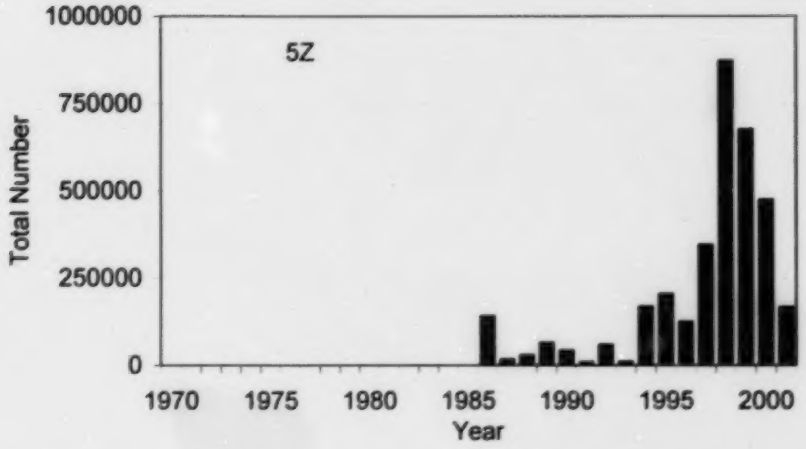


Figure 18. Total number of barndoor skate estimated from the Februrary Georges Bank research vessel survey.

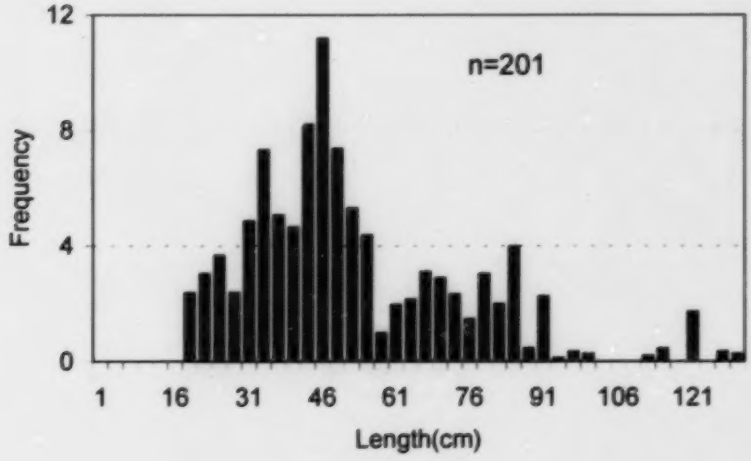


Figure 19. Stratified length frequency of barndoor skate from the February, Georges Bank research vessel survey, 1986-2001.

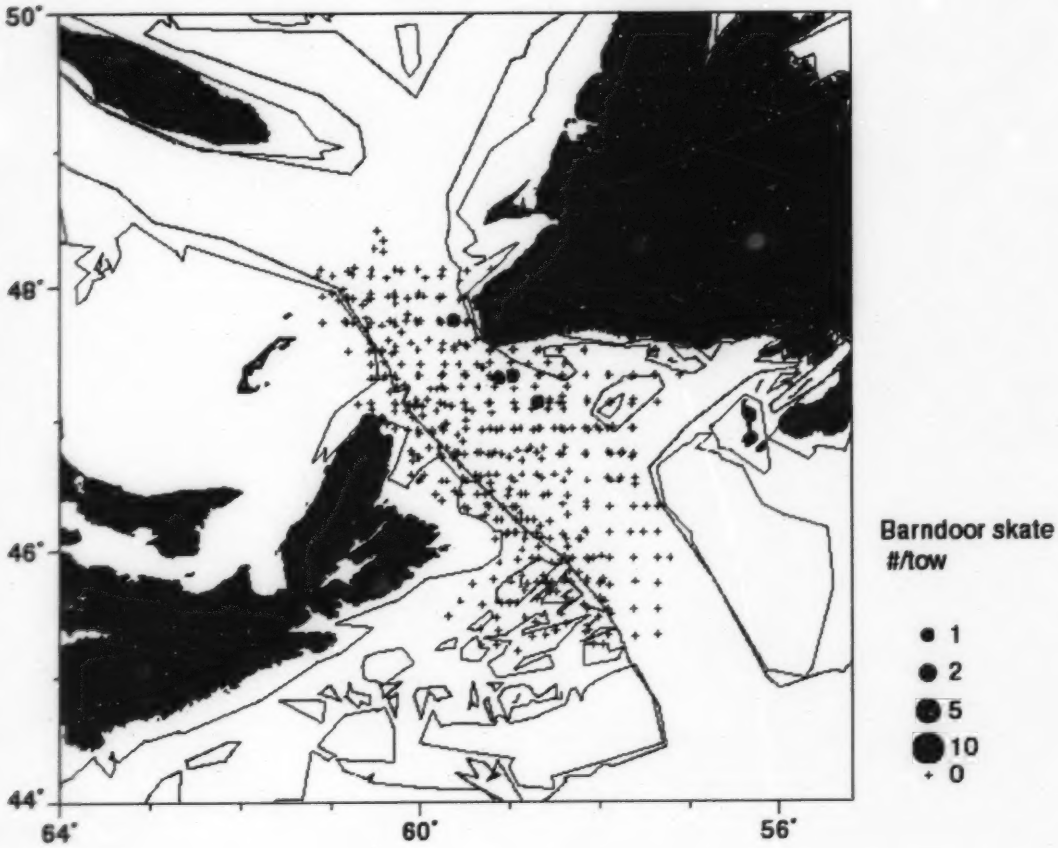


Figure 20 . Number per tow of barndoor skate from the January research vessel survey in the Cabot Strait, 1994-1997.

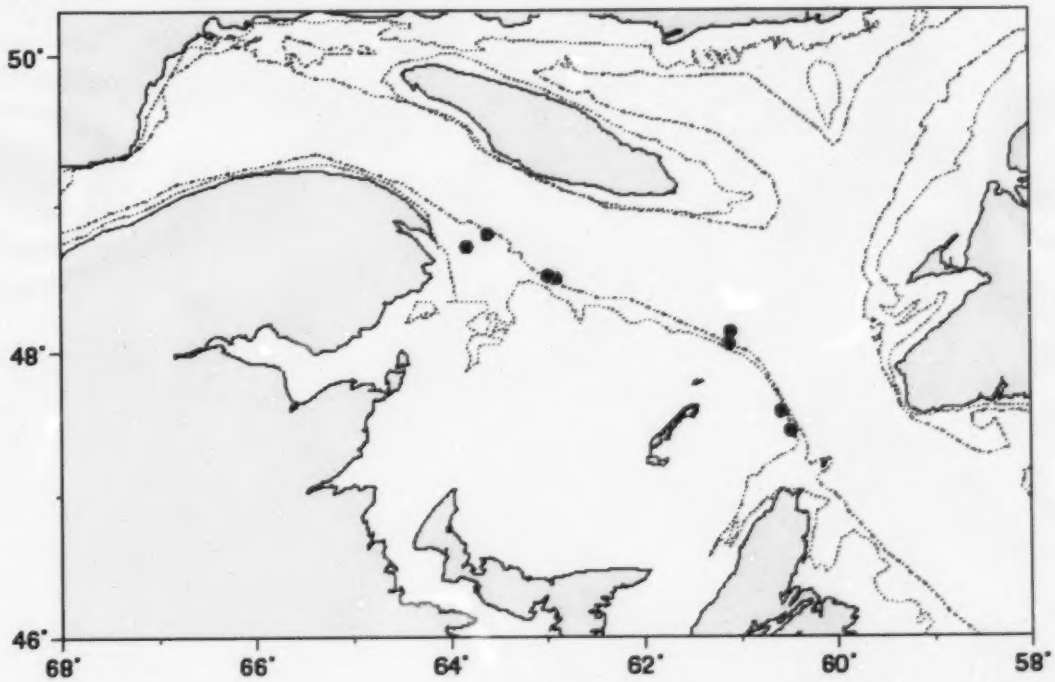


Figure 21. Location of barndoor skate in the Gulf of St. Lawrence September research vessel survey from 1971-2001. Note that only set locations with barndoor skate are shown.

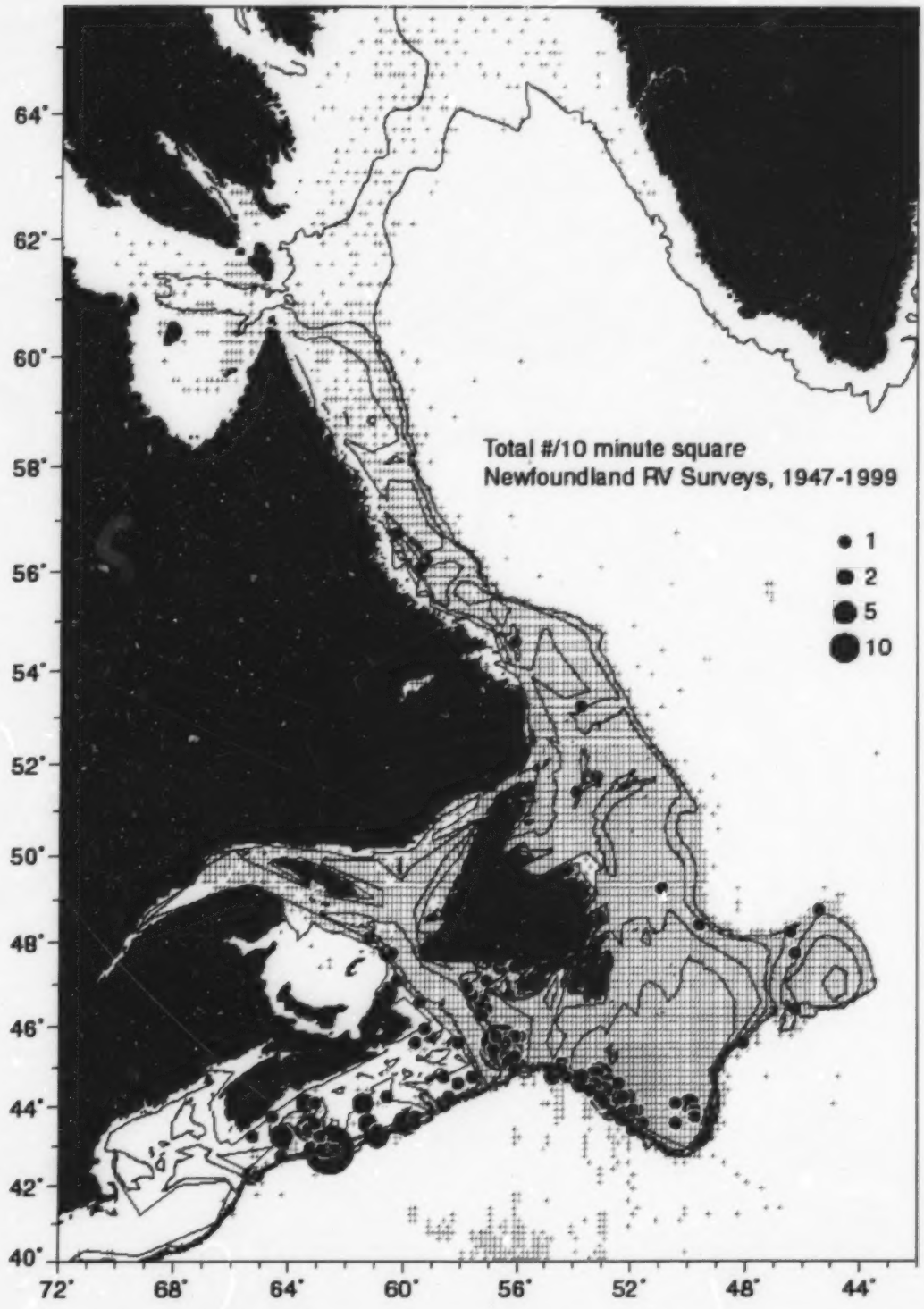


Figure 22. Total number of barndoor skate per 10 minute square from the Newfoundland research vessel surveys, 1947-1999.

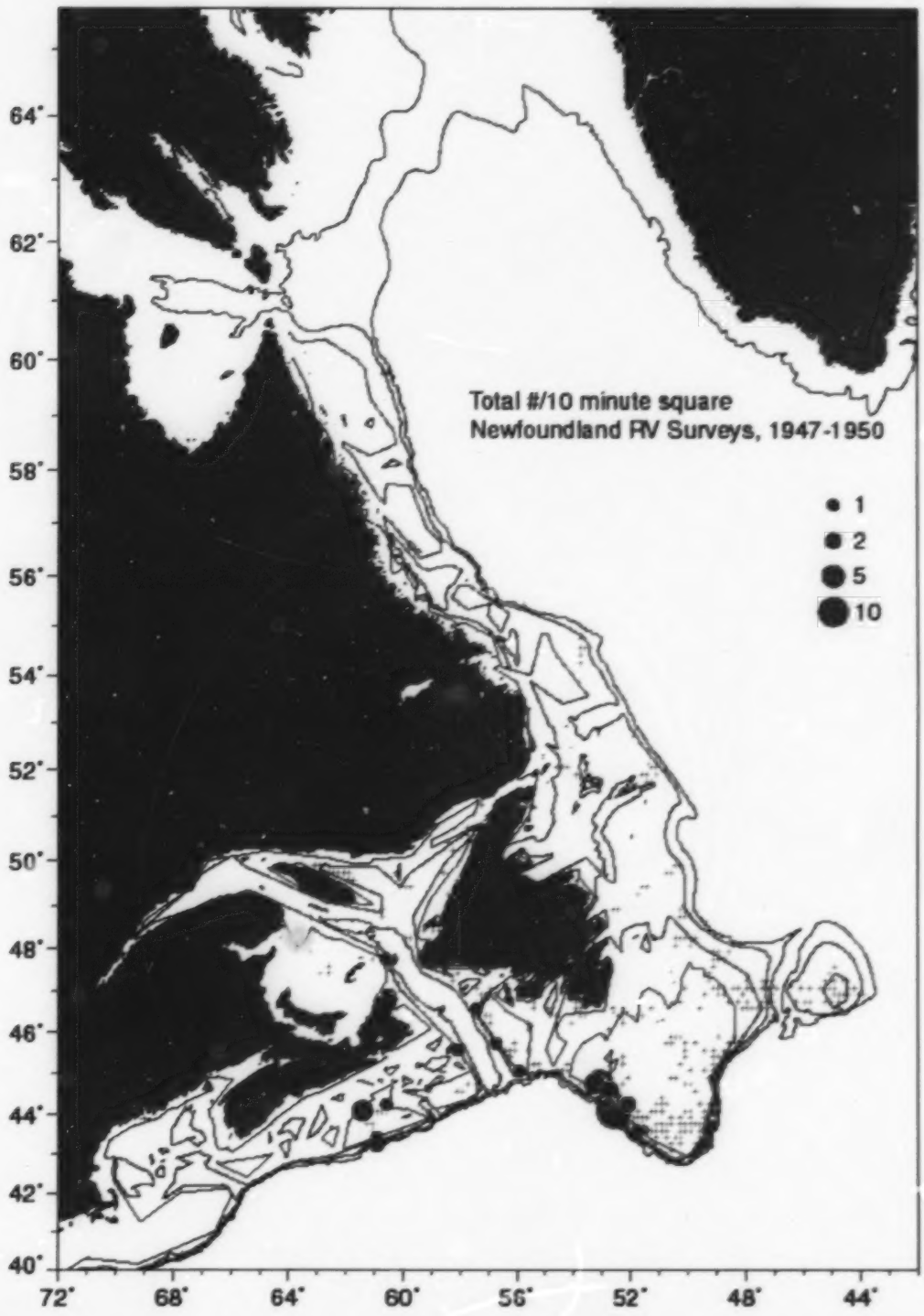


Figure 23. Total number of barndoor skate per 10 minute square from the Newfoundland research vessel surveys, 1947-1950.

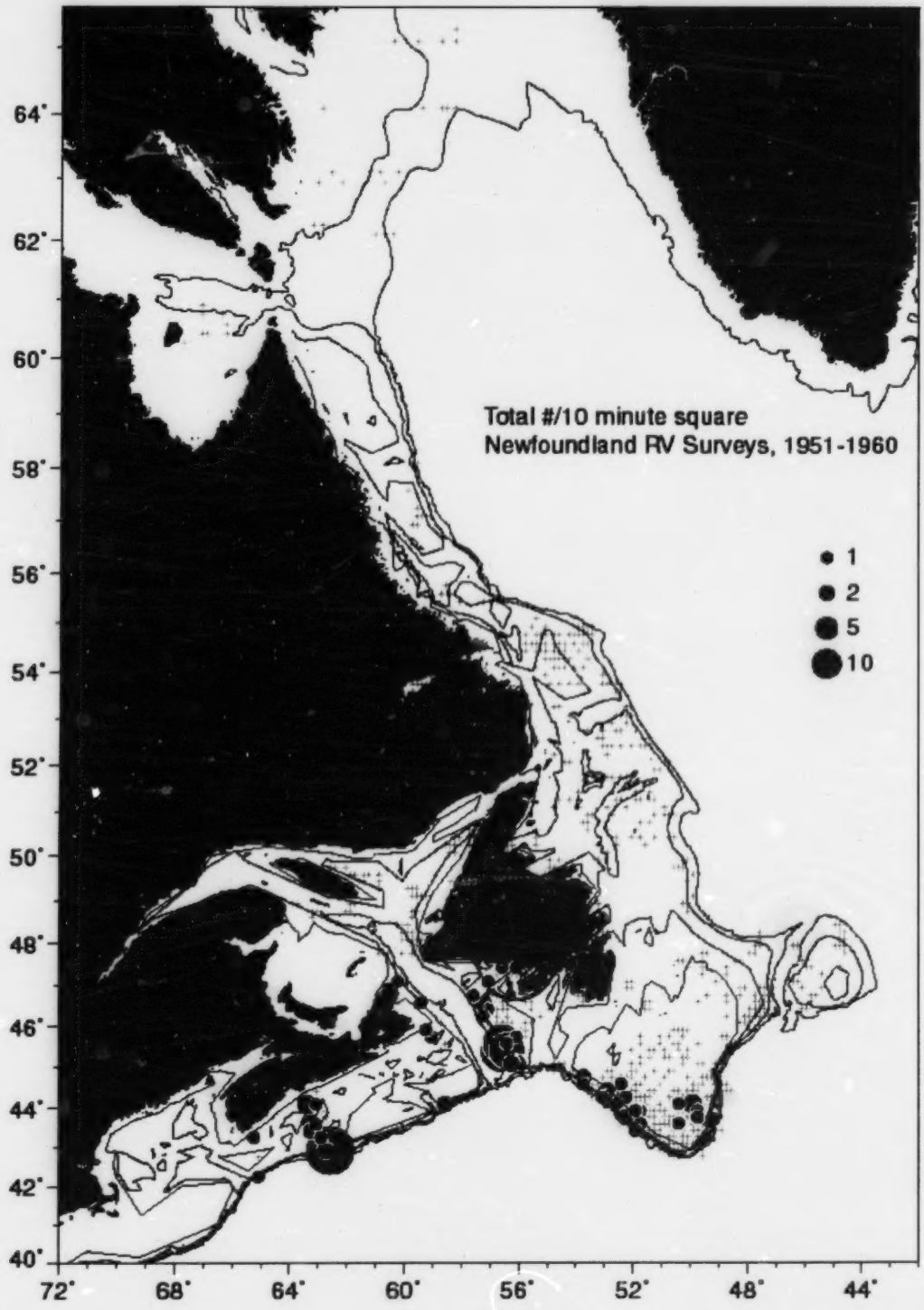


Figure 24. Total number of barndoor skate per 10 minute square from the Newfoundland research vessel surveys, 1951-1960.

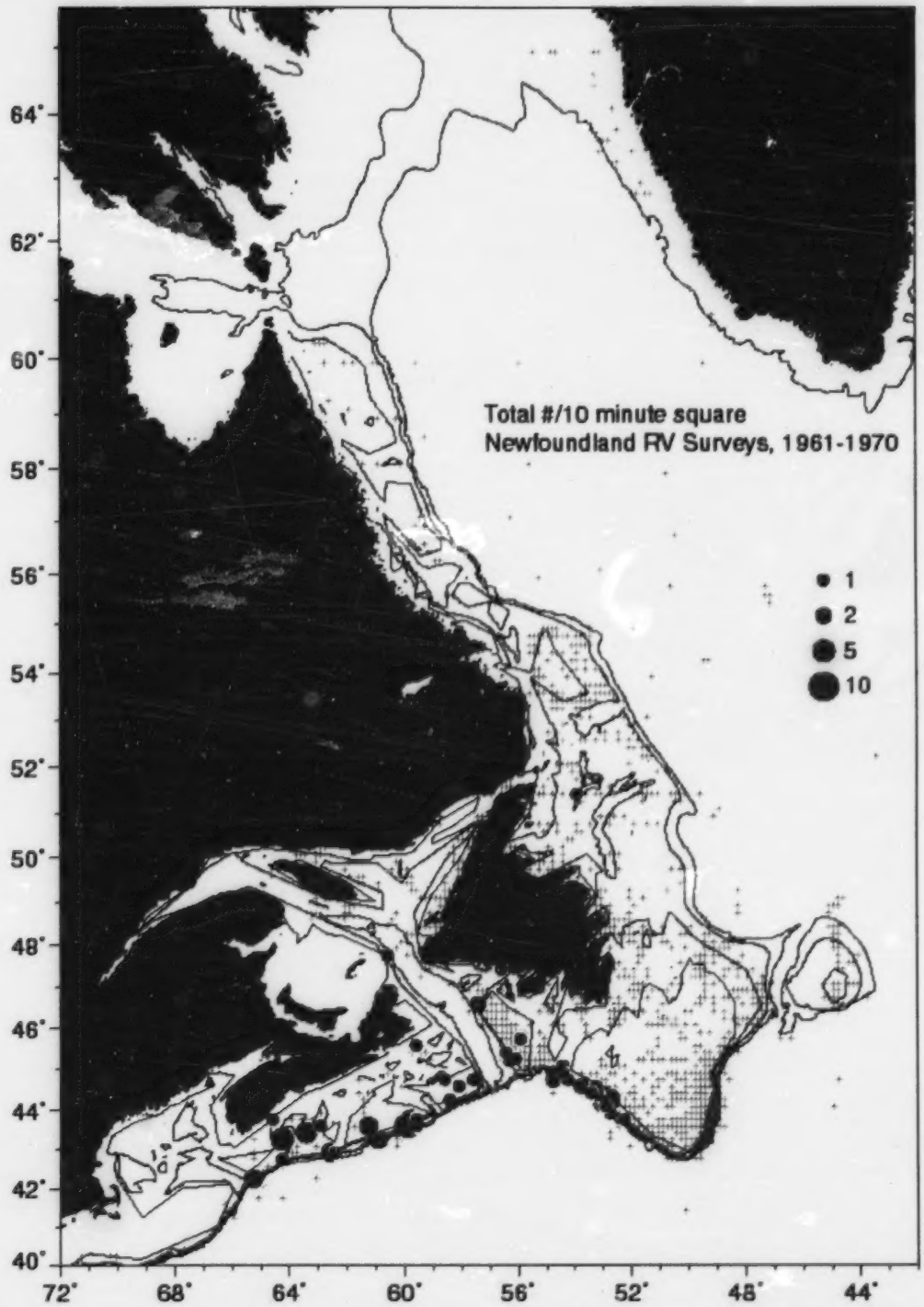


Figure 25. Total number of barndoor skate per 10 minute square from the Newfoundland research vessel surveys, 1961-1970.

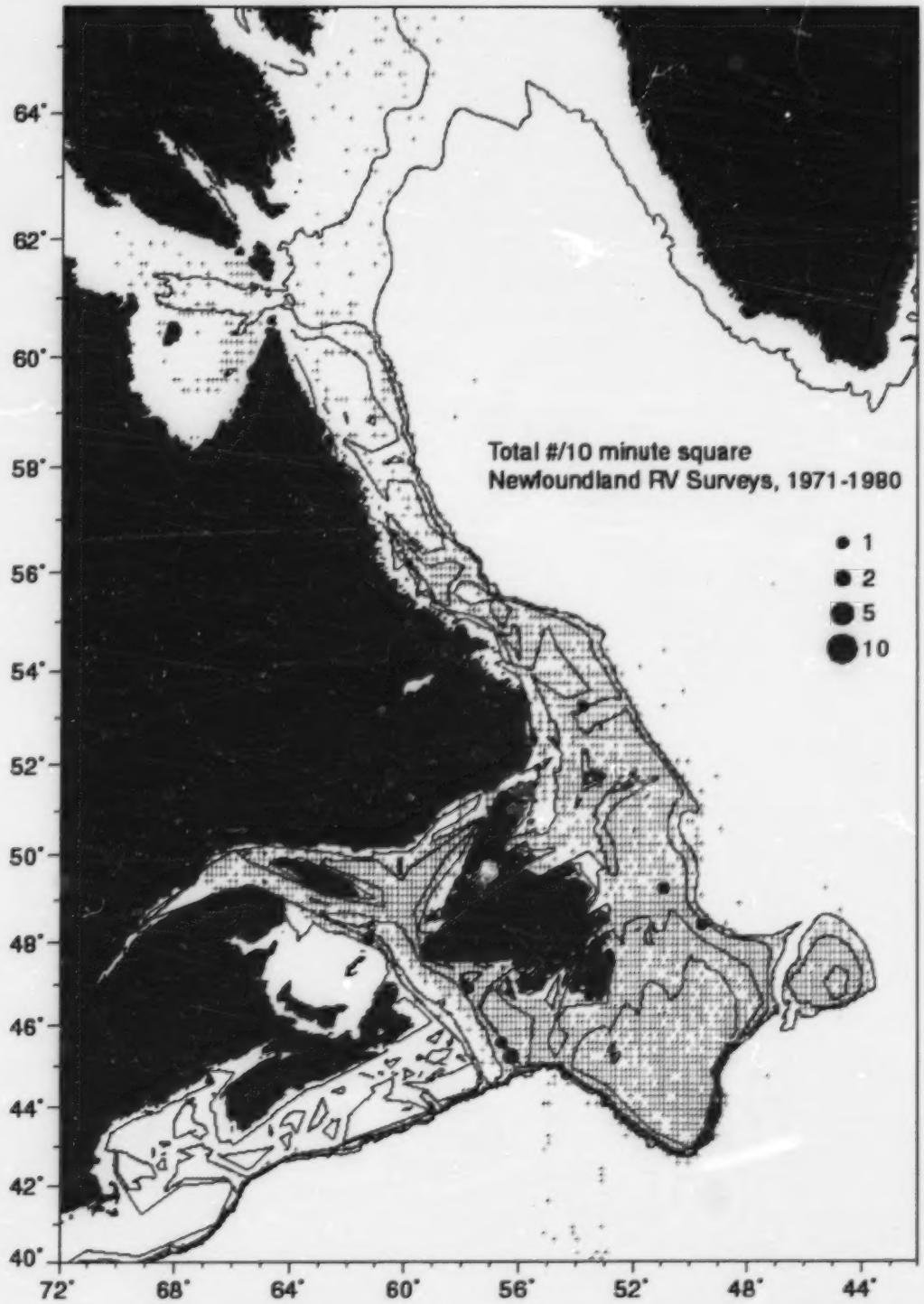


Figure 26. Total number of barndoor skate per 10 minute square from the Newfoundland research vessel surveys, 1971-1980.

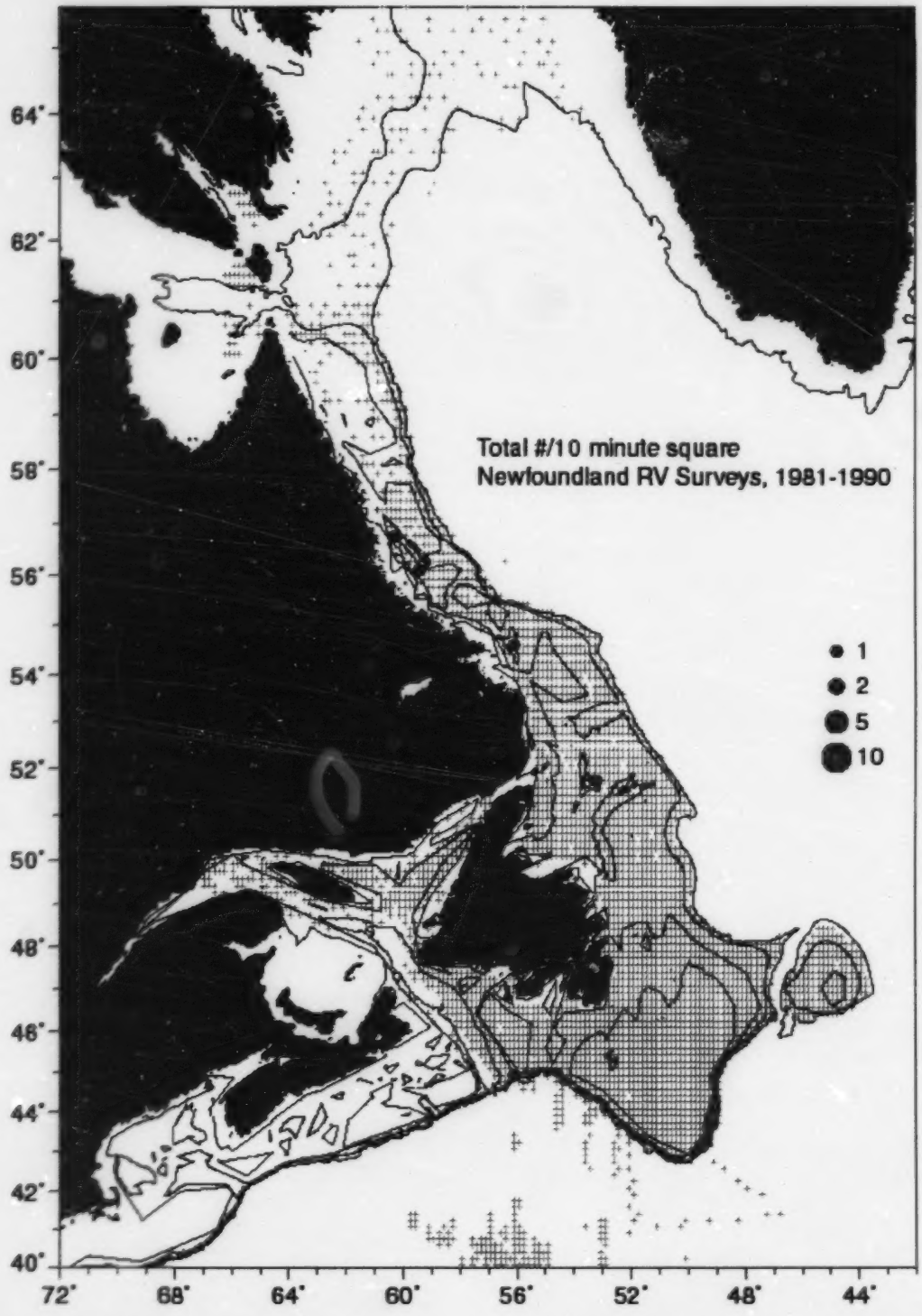


Figure 27. Total number of barndoor skate per 10 minute square from the Newfoundland research vessel surveys, 1981-1990.

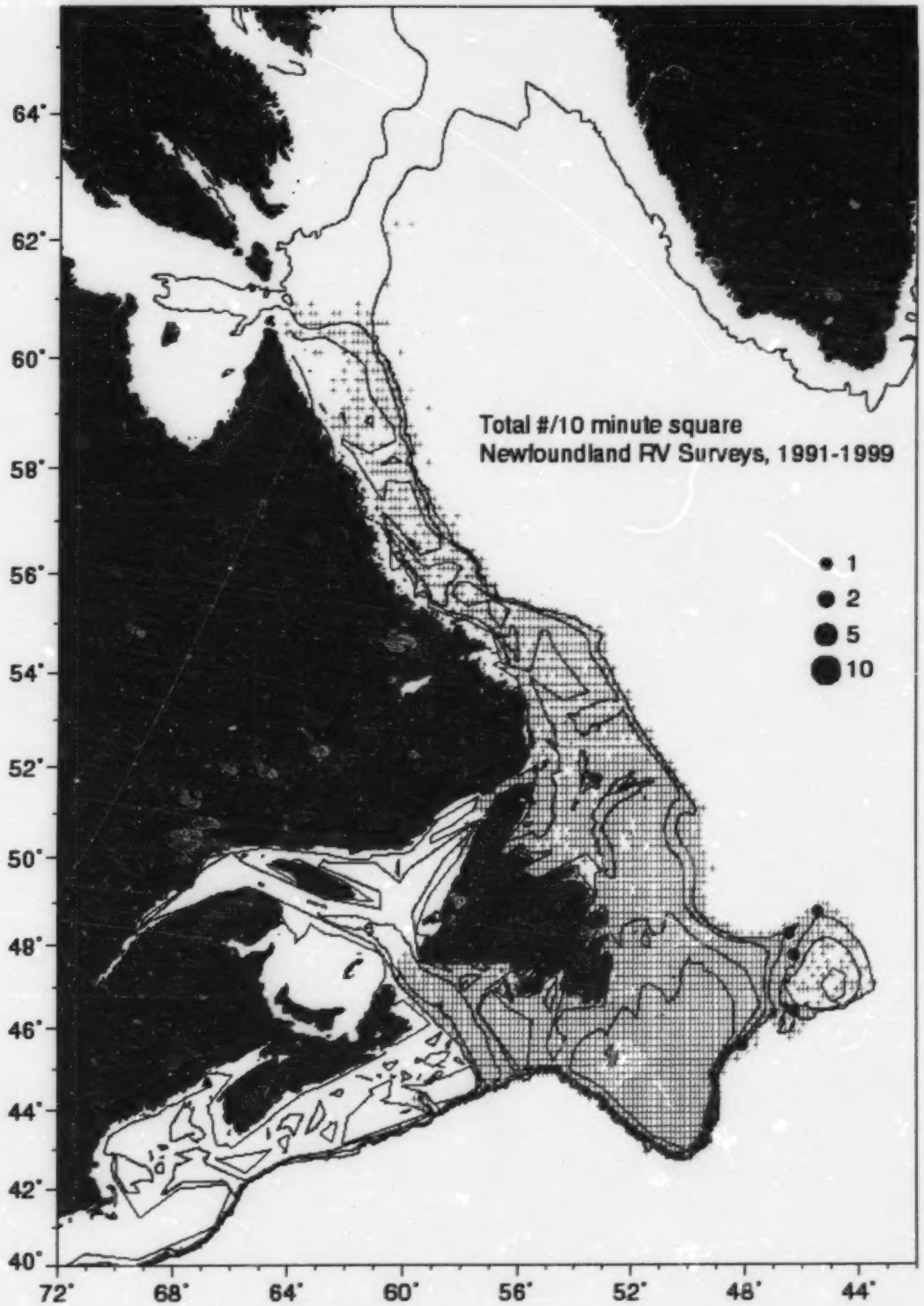


Figure 28. Total number of barndoor skate per 10 minute tow from the Newfoundland research vessel surveys, 1991-1999.

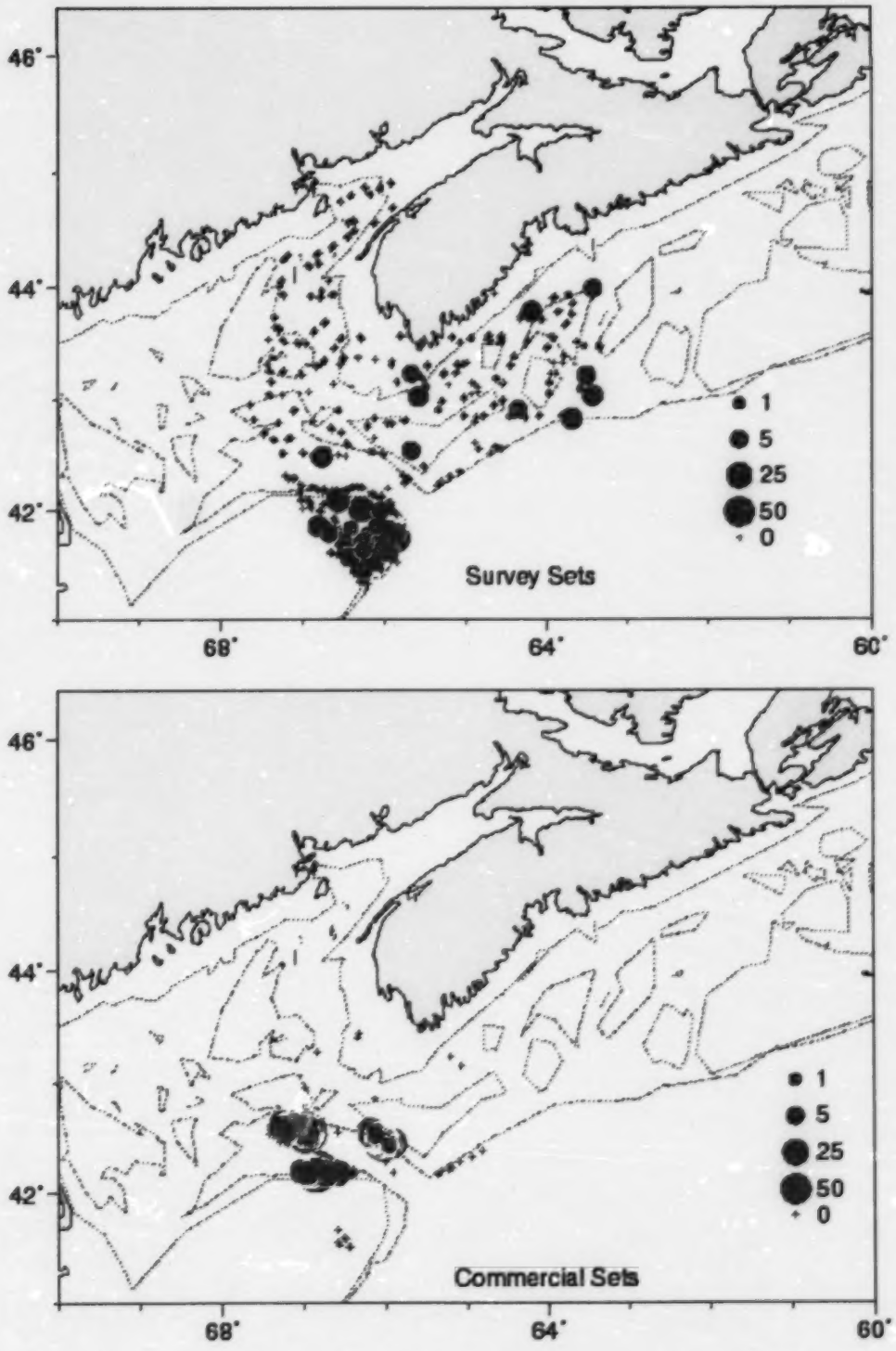


Figure 29. Abundance (kg/set) of barndoor skate captured during the Monkfish Industry/Science Survey and the associated commercial sets, 1995-1999.+

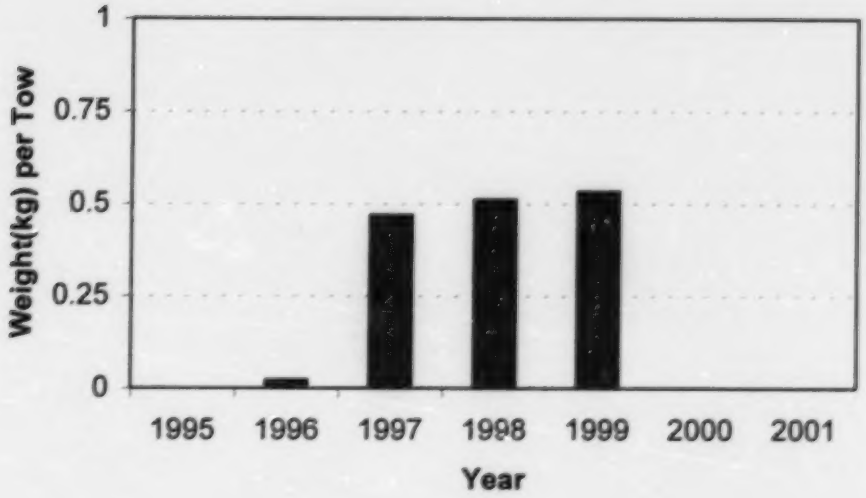


Figure 30. Mean catch (kg) per tow of barndoor skate from the monkfish Industry/Science Surveys in Div. 4X5Z, 1995-1999. Note: Skate were not identified to species in 1995.

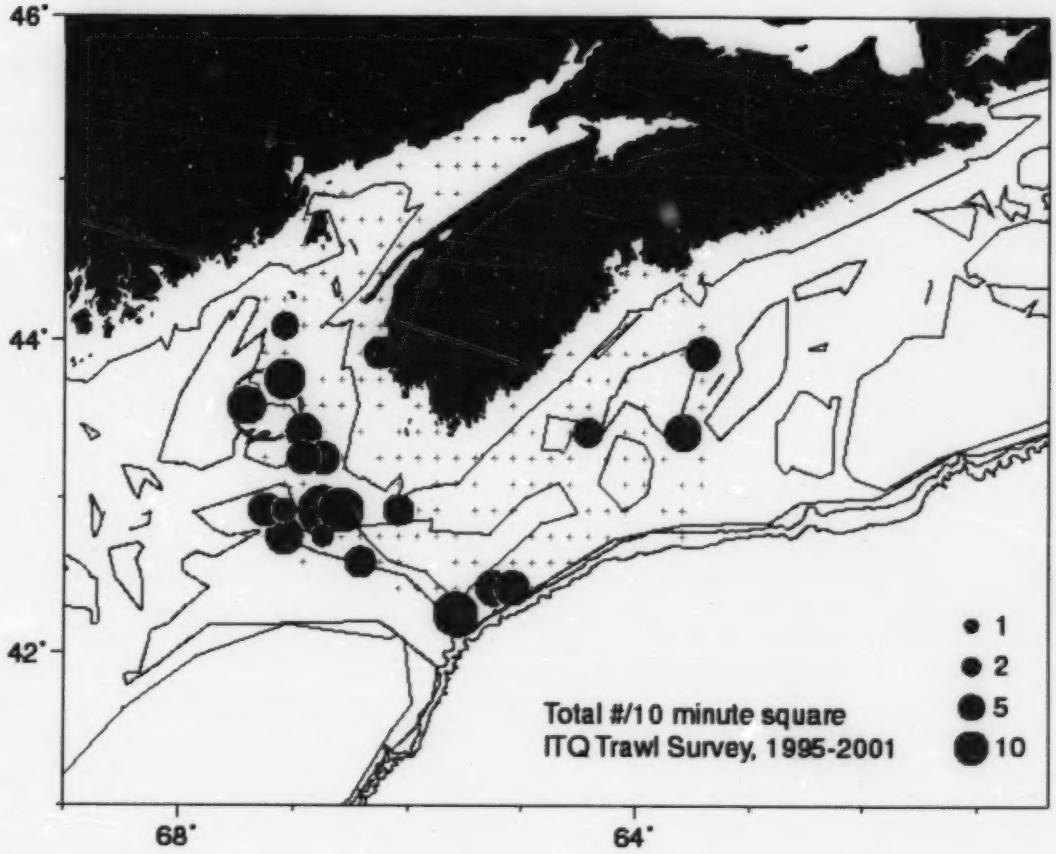


Figure 31. Total number of barndoor skate per 10 minute square from the ITQ Industry Science Surveys, 1995-2001.

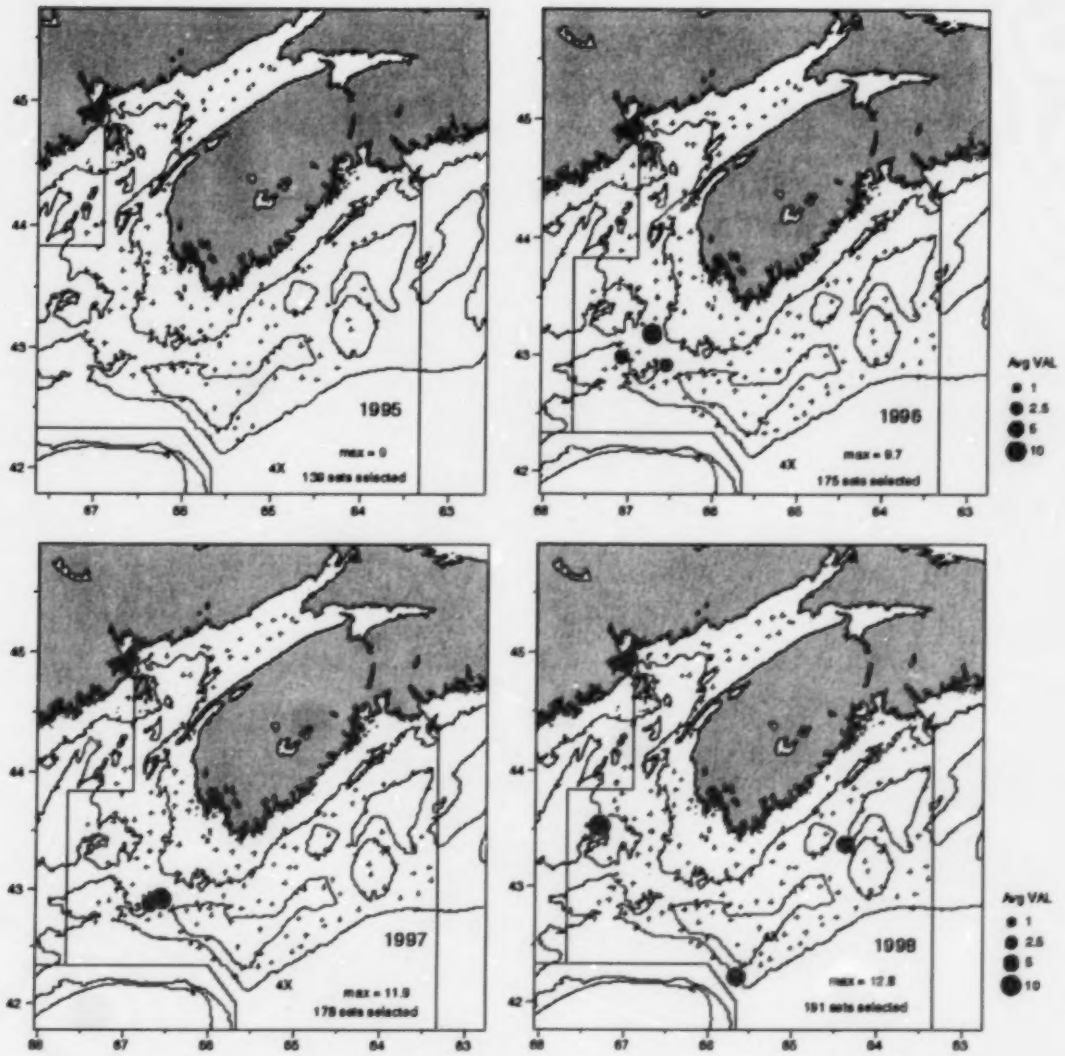


Figure 32. Abundance (kg) per tow of barndoor skate from the ITQ Industry Science Survey in Div. 4X, 1995-2001.

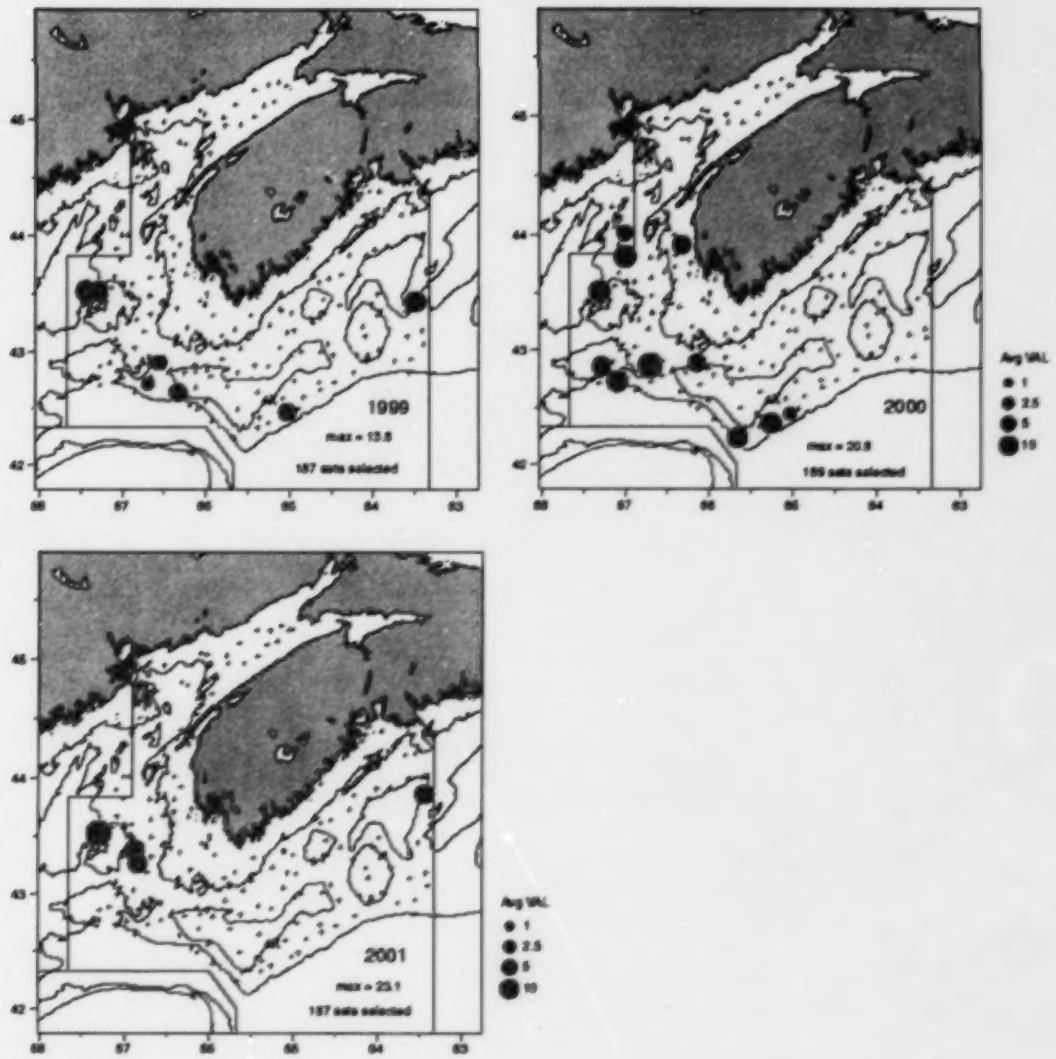


Figure 32. (cont'd).

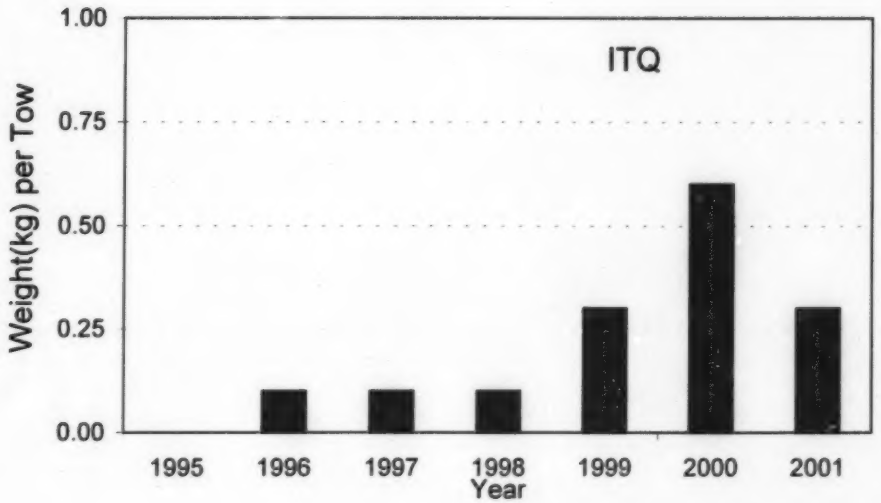


Figure 33. Mean catch(kg) per tow barndoor skate from the Div. 4X ITQ Industry/Science Survey.

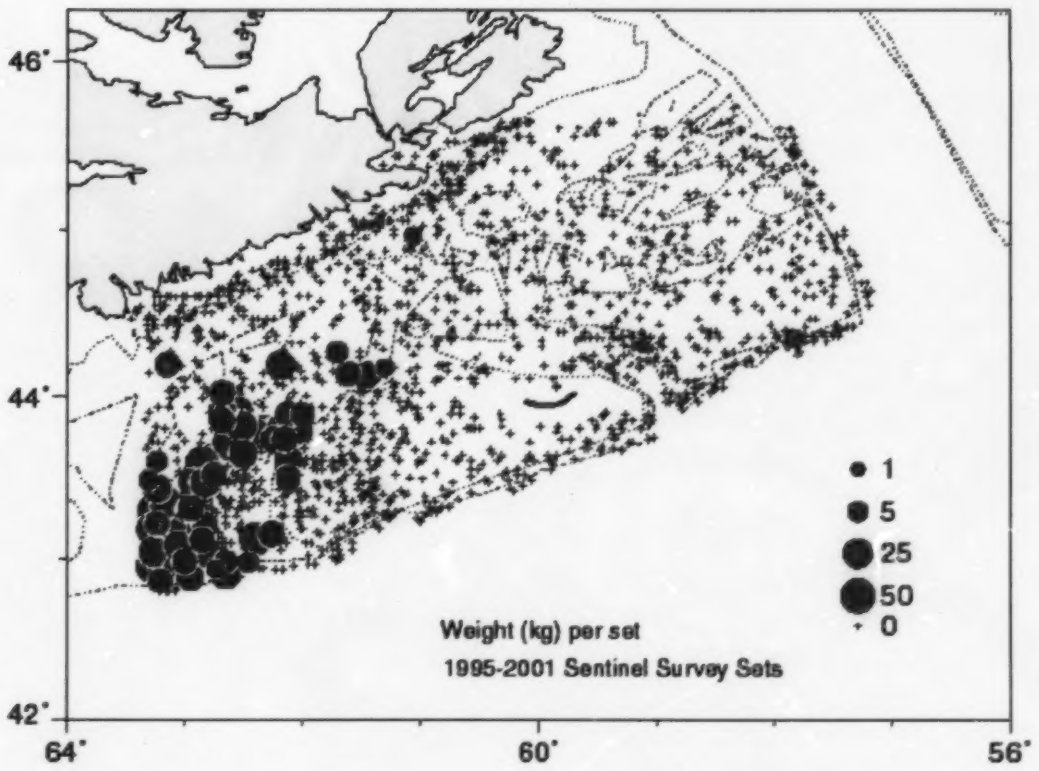


Figure 34. Abundance (kg/set) of barndoor skate from the longline Sentinel Survey in Div. 4VsW, 1995-2001.

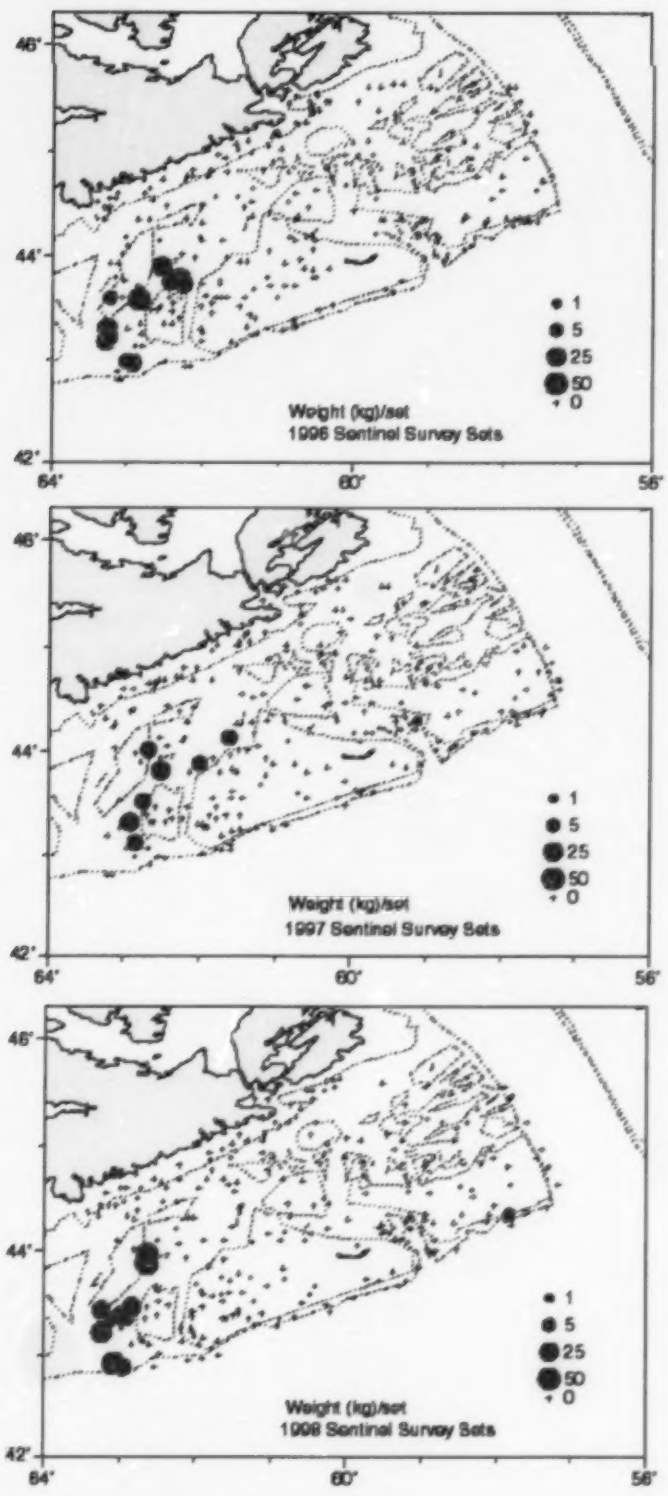


Figure 35. Patterns of abundance (kg/set) of barndoor skate from the longline Sentinel Survey in Div. 4VsW, 1996-1998.

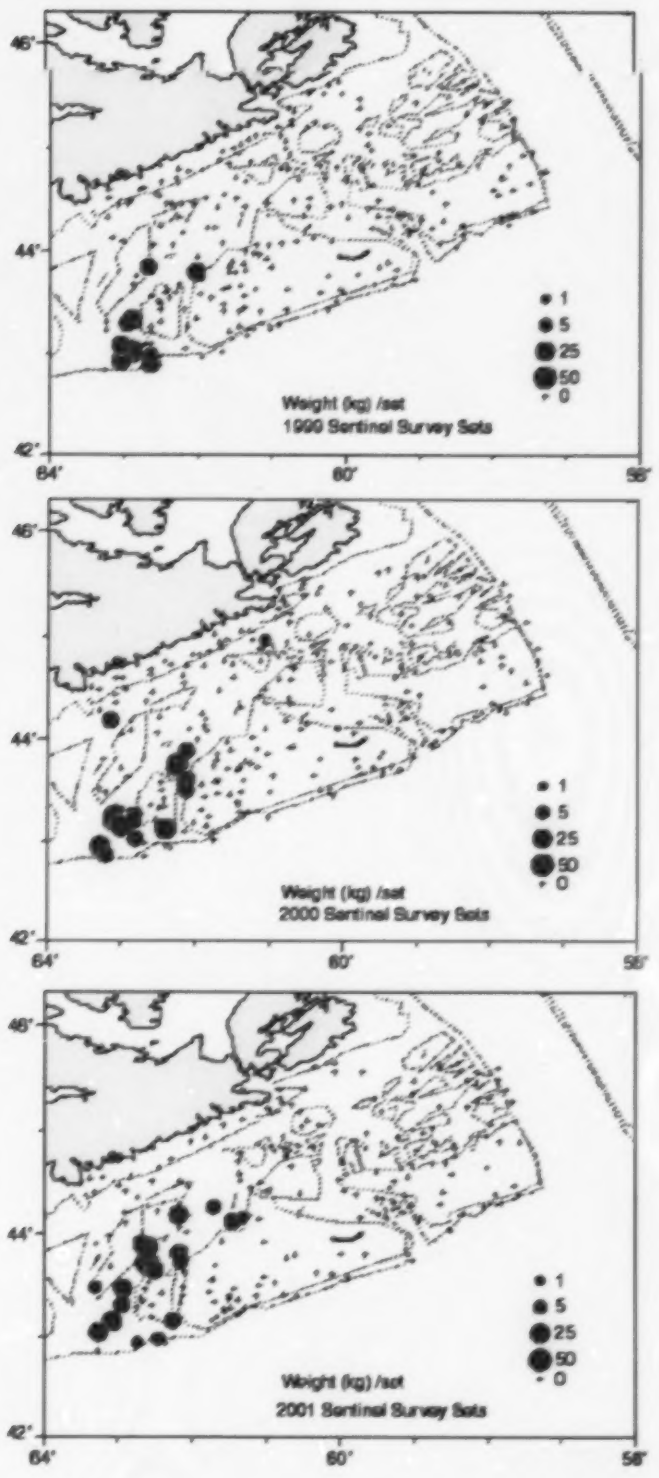


Figure 38. Patterns of abundance (kg/set) of barndoor skate from the longline Sentinel Survey in Div. 4VsW, 1999-2001.

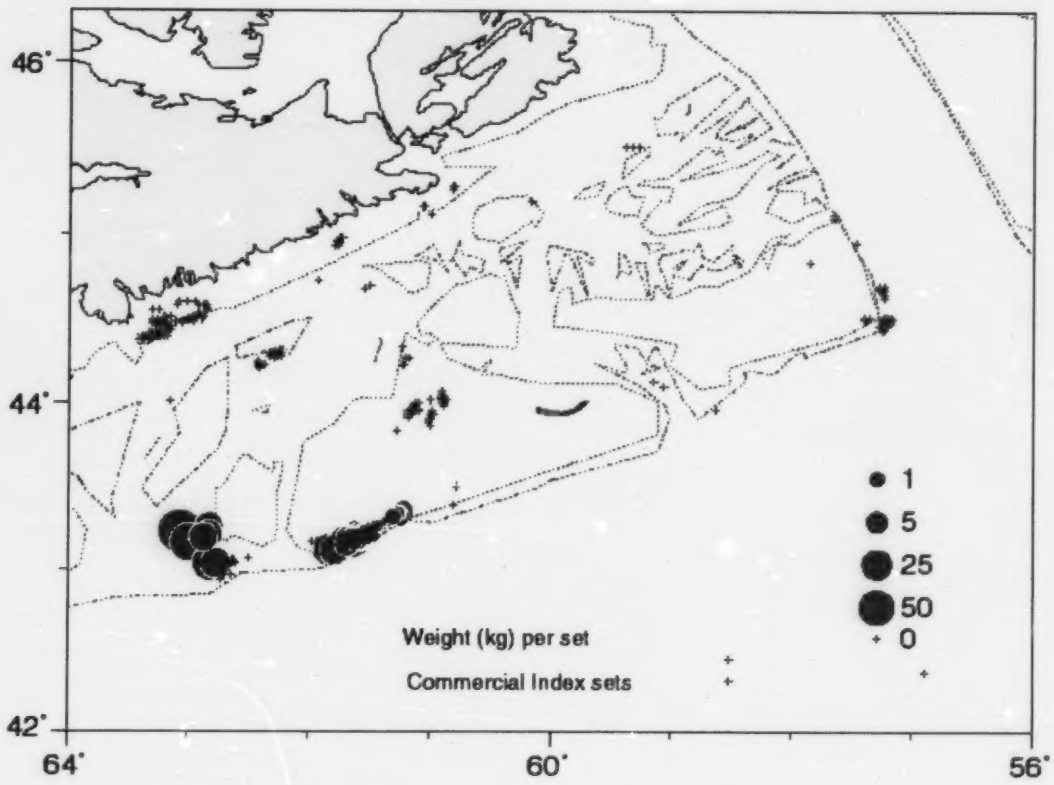


Figure 37. Patterns of abundance (kg/set) of barndoor skate from the commercial index sets of the longline Sentinel Survey, conducted from 1996-2001.

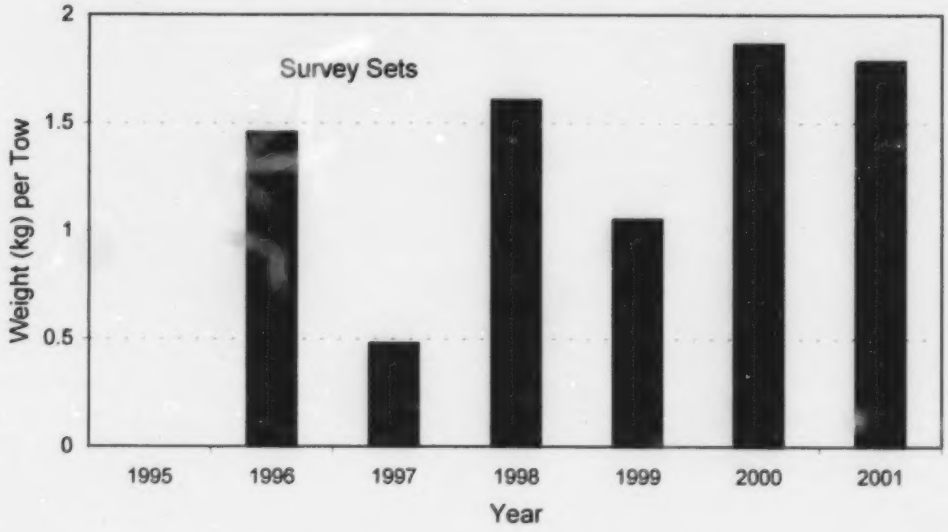


Figure 38. Mean catch rate (kg/set) of barndoor skate from the longline Sentinel Survey in Div. 4VsW. Note: Skates were not identified to the species level during 1995.

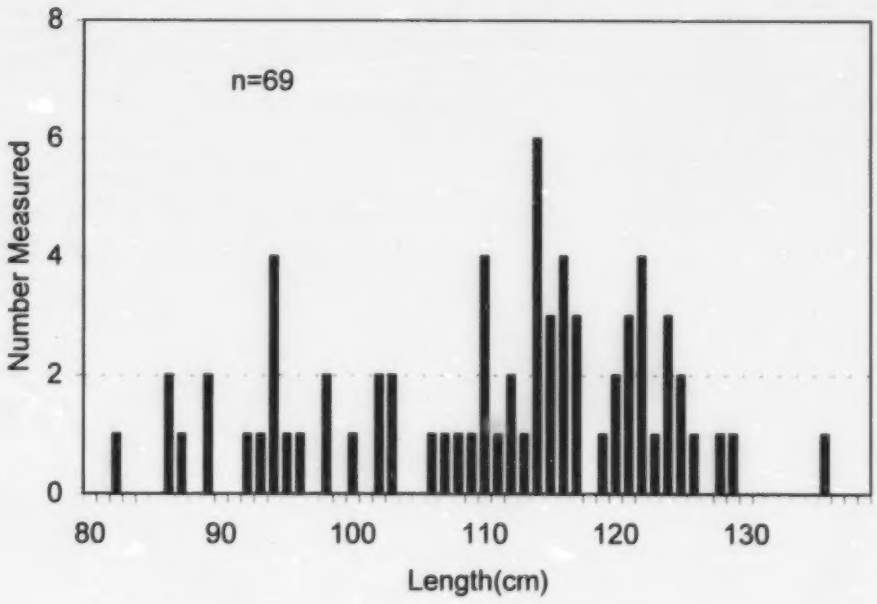


Figure 39. Length frequency of barndoor skate caught in the longline Sentinel Survey. in Div. 4VsW

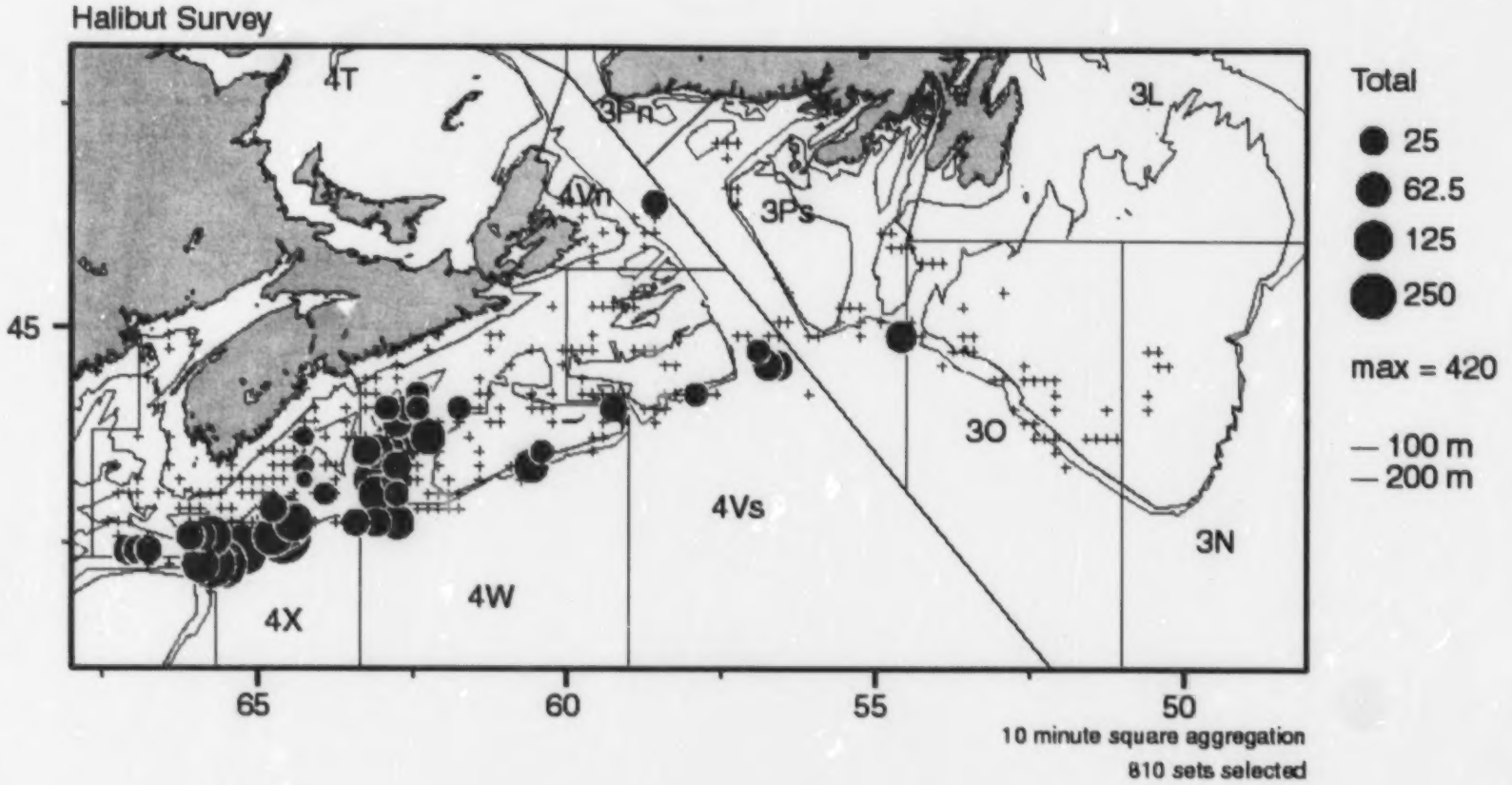


Figure 40. Total abundance (kg) of barndoor skate per 10 minute square from the survey sets of the longline Halibut Industry Science Survey, 1998 - 2001.

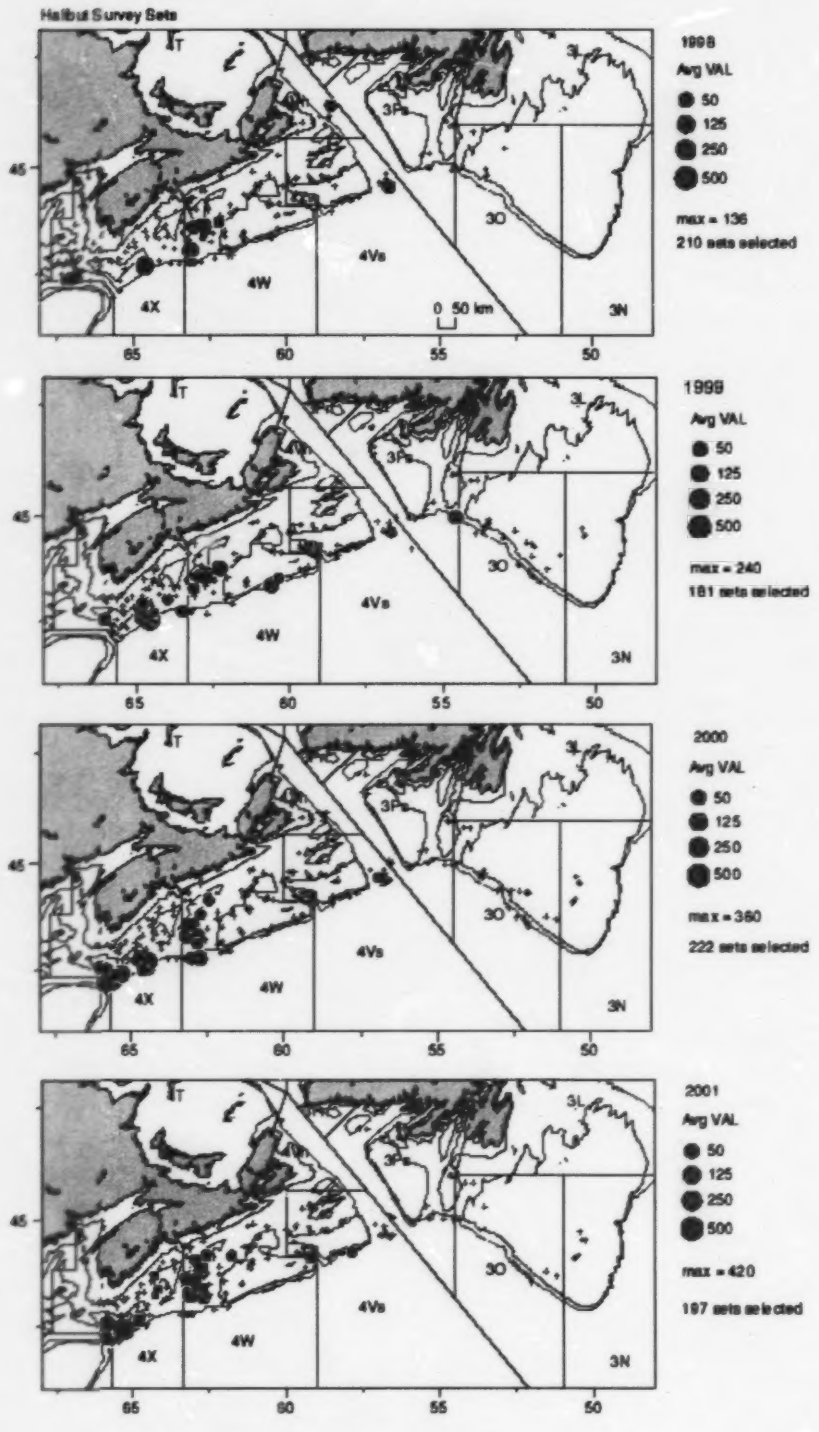


Figure 41. Abundance (kg/set) of barndoor skate from the Halibut Industry Science Survey in Div. 3NOP4VWX, 1998-2001.

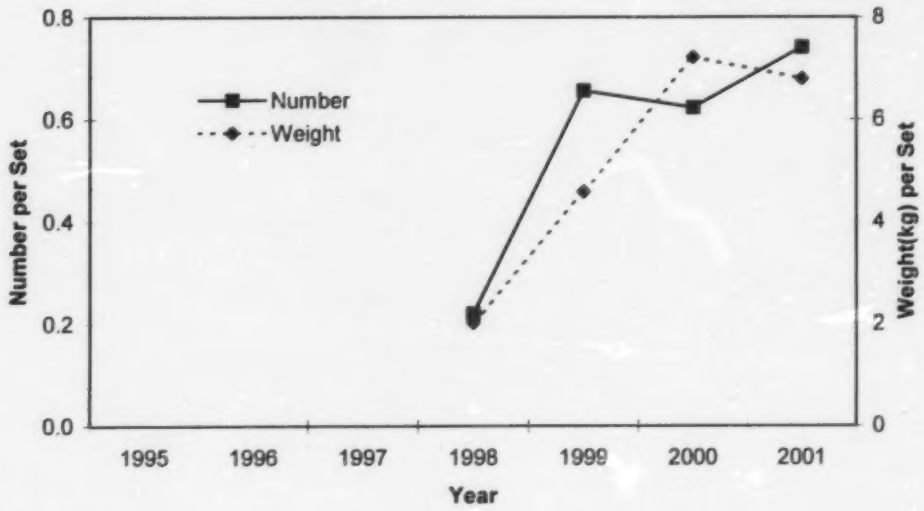


Figure 42. Average number and weight(kg) per set of barndoor skate caught in Divs. 3NOP4VWX by the Halibut Industry Science Survey, 1998-2001.

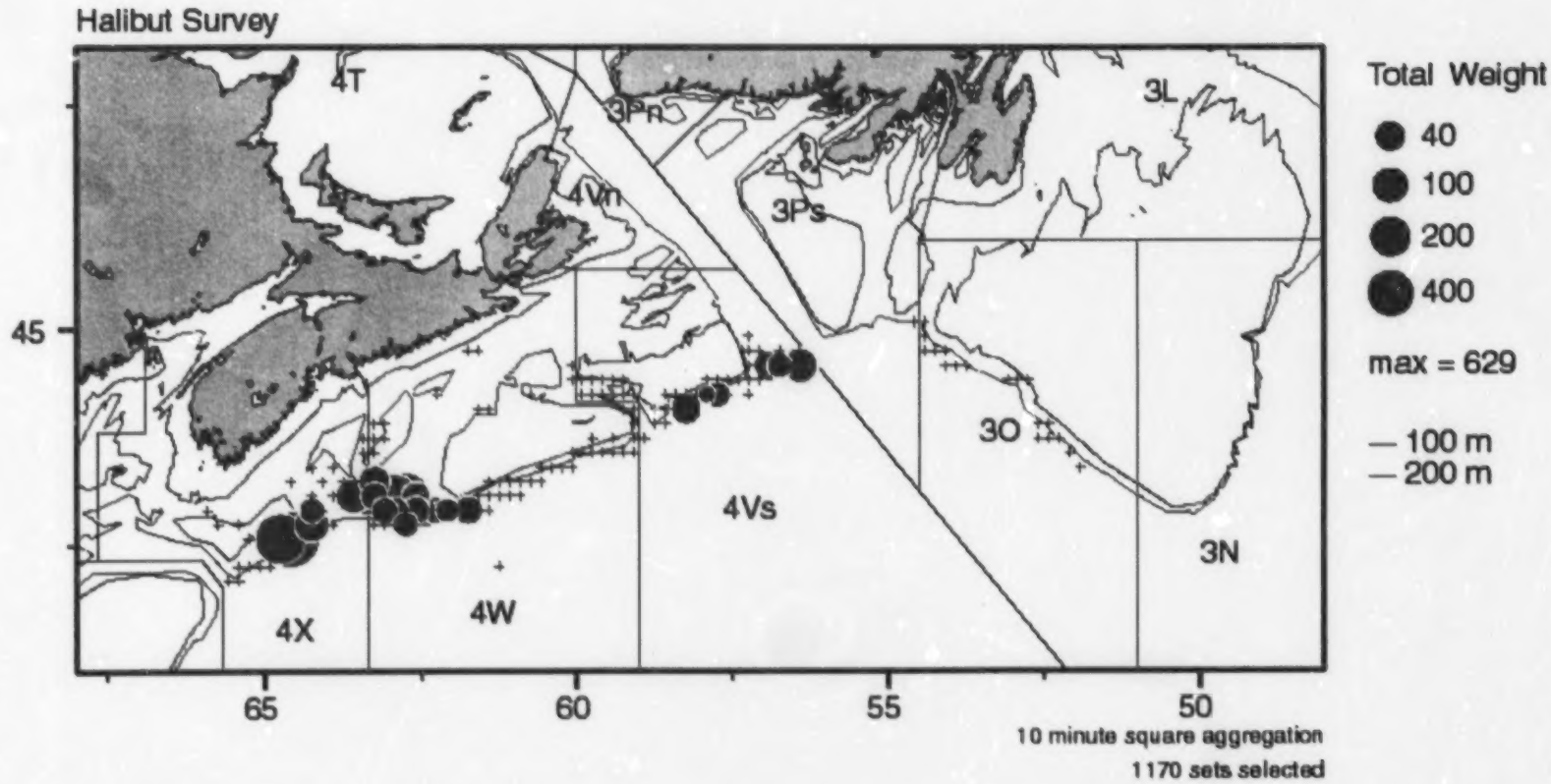


Figure 43. Total abundance (kg) of barndoor skate per 10 minute square from the commercial index sets of the longline Halibut Industry Science Survey.

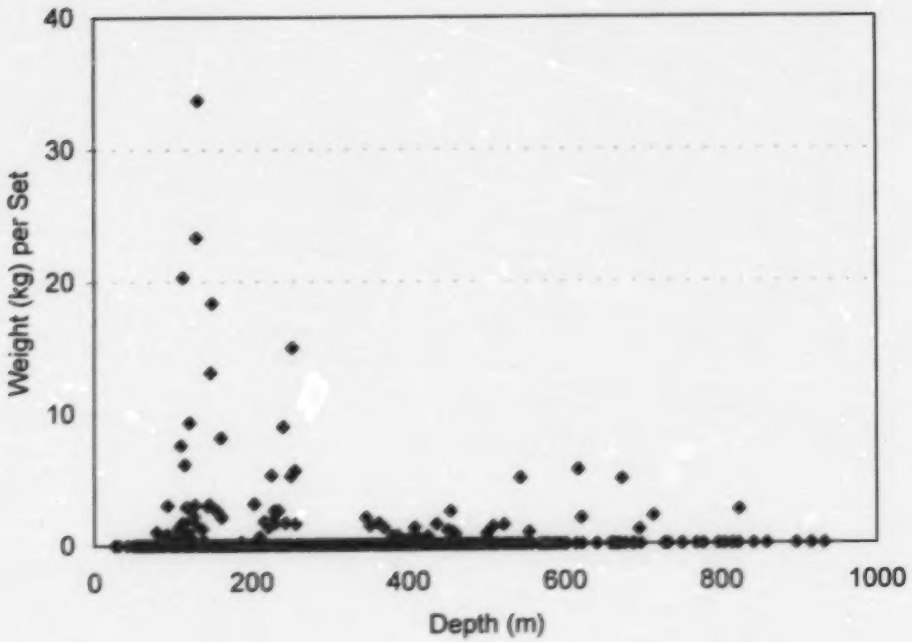


Figure 44. Catch rate(kg) at depth of barndoor skate from the Halibut Industry Science Survey including survey and commercial index sets.

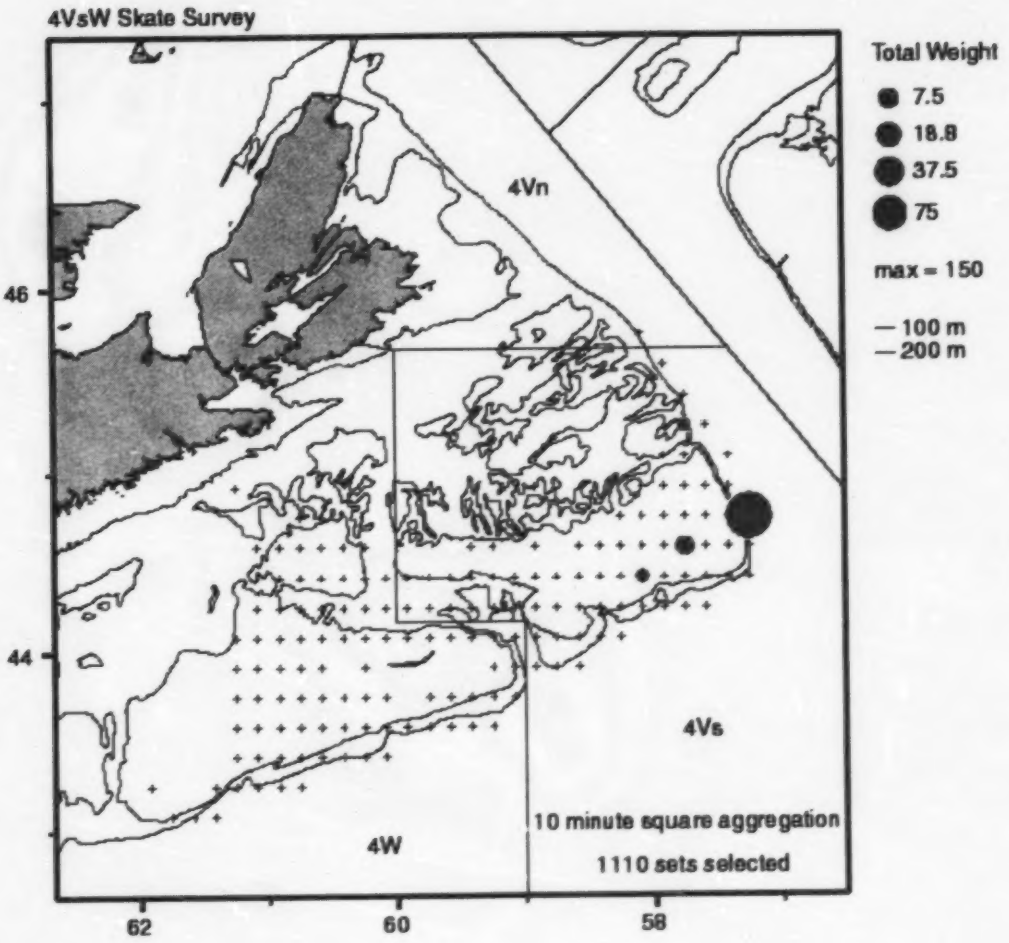
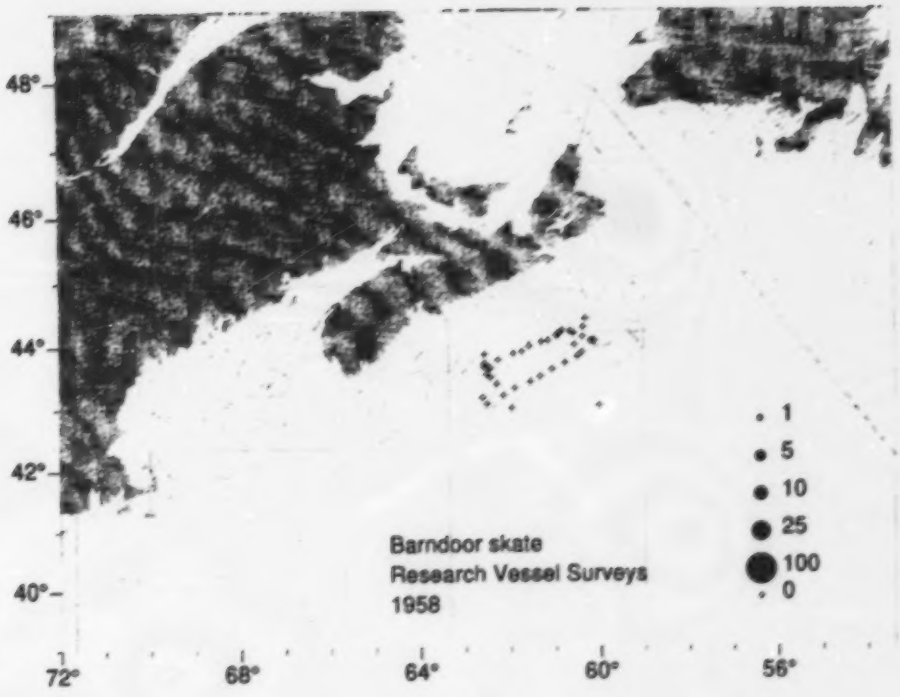
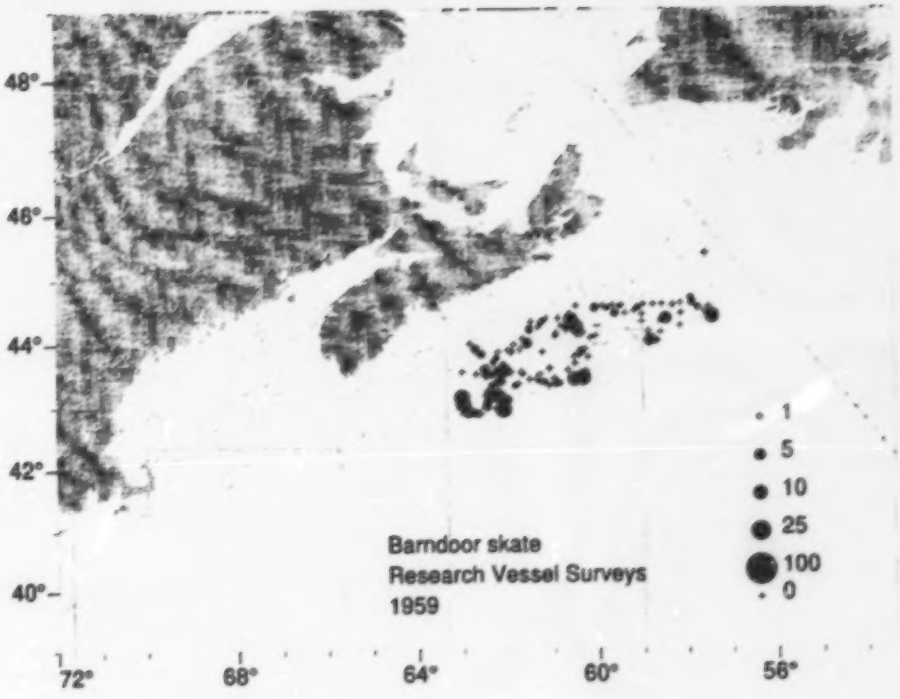


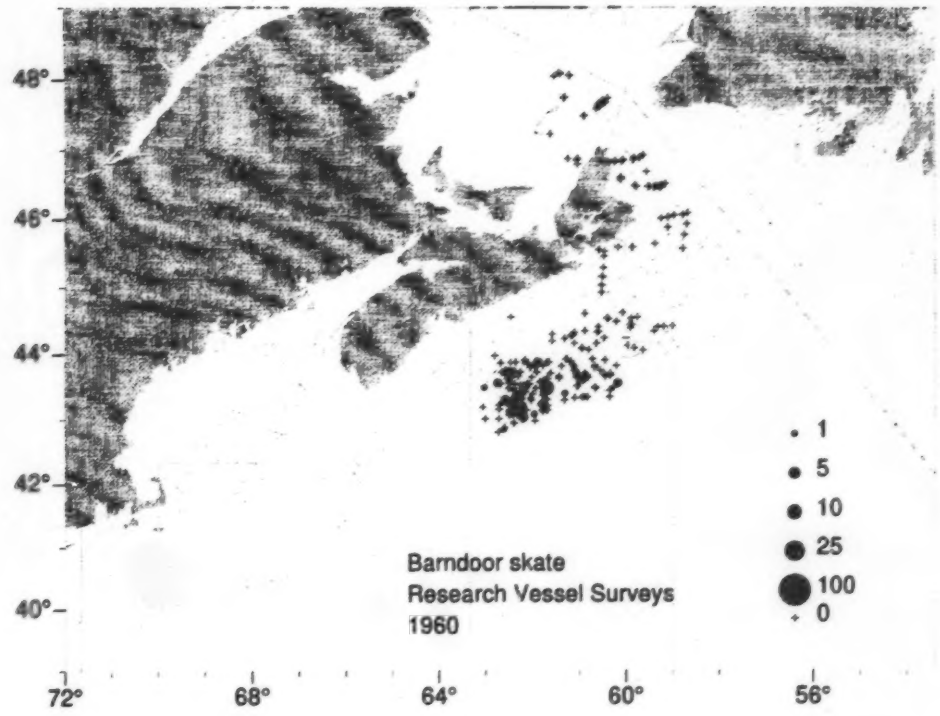
Figure 45. Total abundance (kg) of barndoor skate per 10 minute square from the survey and fishermen index sets of the 4VsW Industry/ Science Skate Survey, 1995-2001.

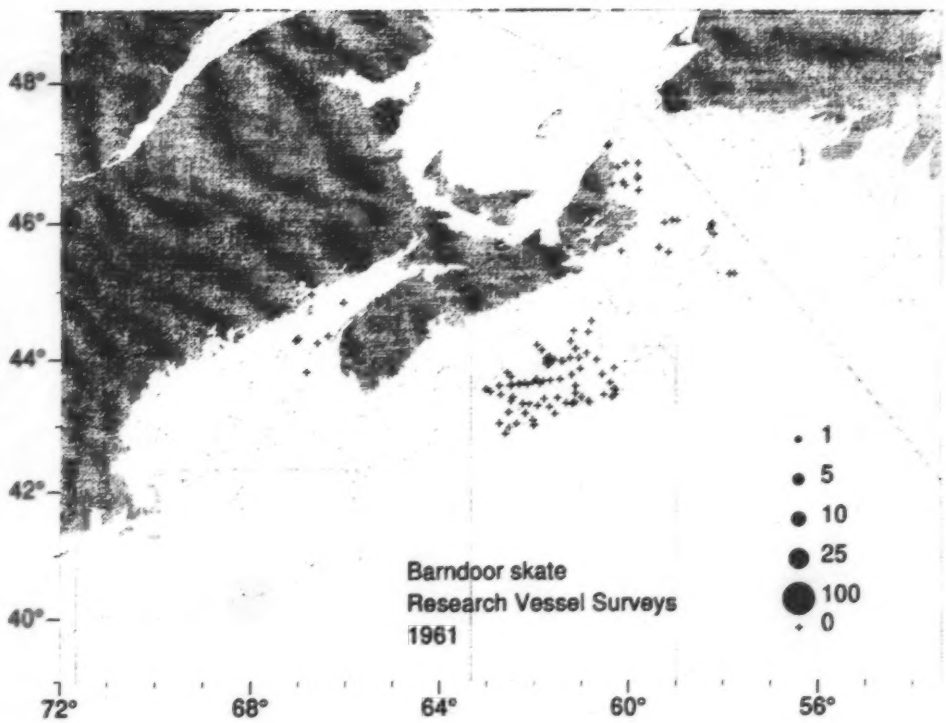
Appendix 1

Non-standard research vessel surveys from NAFO Divs. 3OP4VW5XYZ from 1958-1969 showing distribution of barndoor skate.


48°
46°
44°
42°
40°
72°
68°
64°
60°
56°
Barndoor skate
Research Vessel Surveys
1958
1
5
10
25
100
0


48°
46°
44°
42°
40°
72°
68°
64°
60°
56°
Barndoor skate
Research Vessel Surveys
1959
1
5
10
25
100
0


48°
46°
44°
42°
40°
72°
68°
64°
60°
56°
Barndoor skate
Research Vessel Surveys
1960
1
5
10
25
100
0


48°
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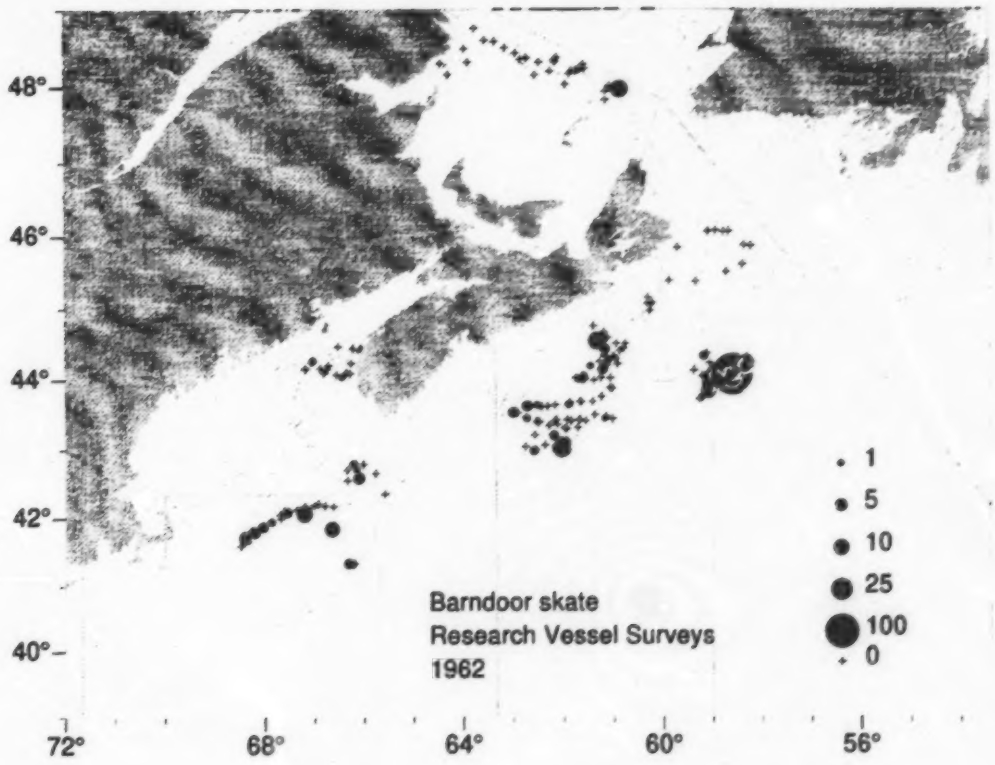
40°
72°
68°
64°
60°
56°
Barndoor skate
Research Vessel Surveys
1961
1
5
10
25
100
0


48°
46°
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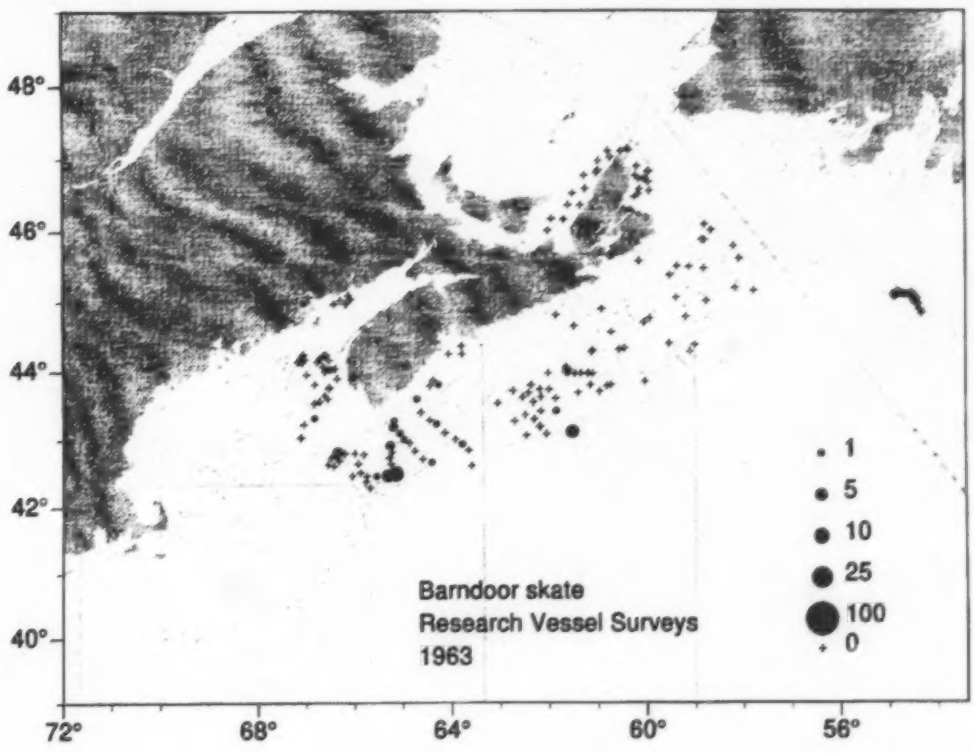
60°
56°
1
5
10
25
100
0
Barndoor skate
Research Vessel Surveys
1962


48°
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60°
56°
1
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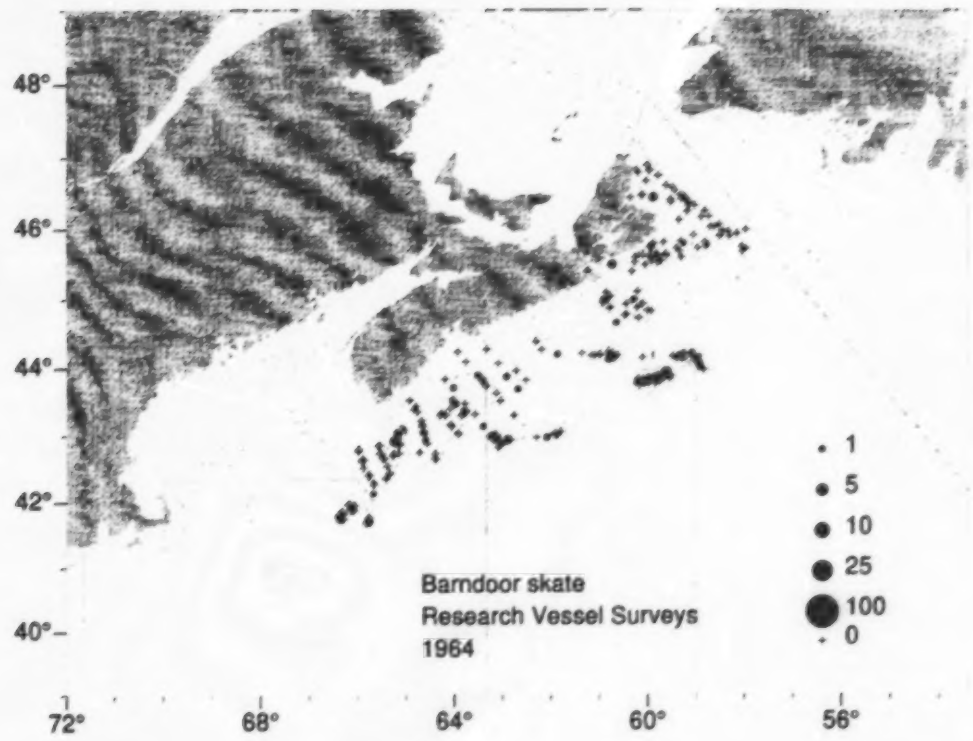
25
100
0
Barndoor skate
Research Vessel Surveys
1963


48°
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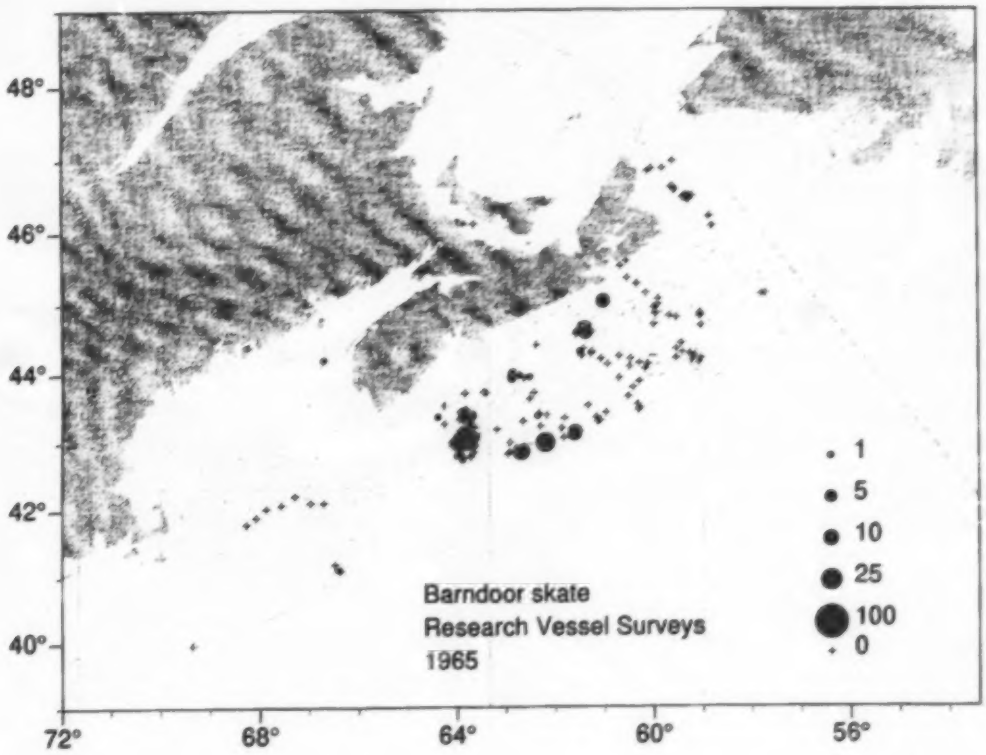
0
Barndoor skate
Research Vessel Surveys
1964


48°
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40°
72°
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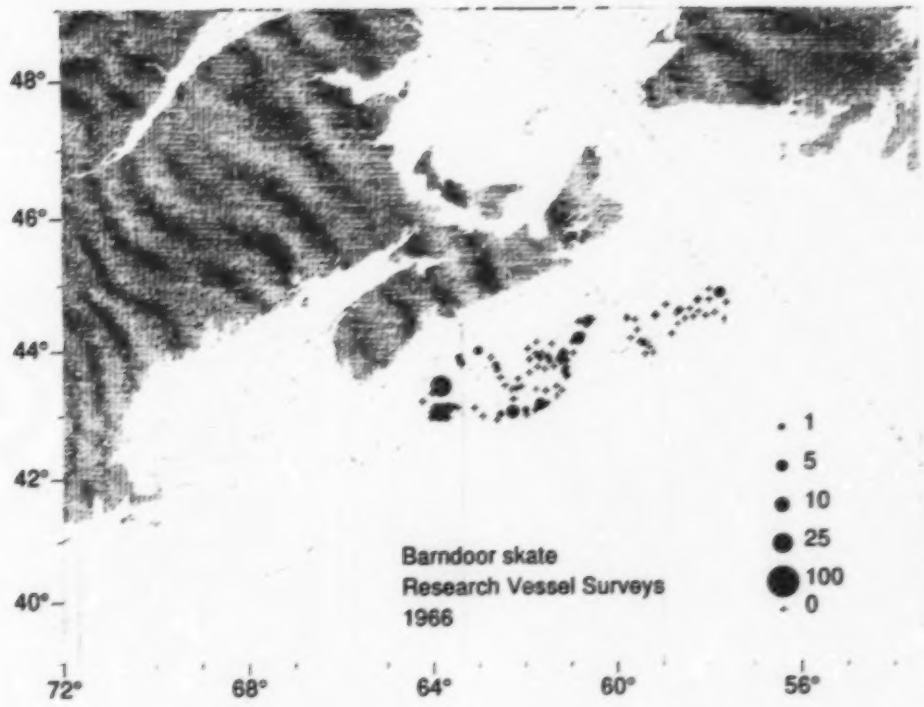
60°
56°
1
5
10
25
100
0
Barndoor skate
Research Vessel Surveys
1965


48°
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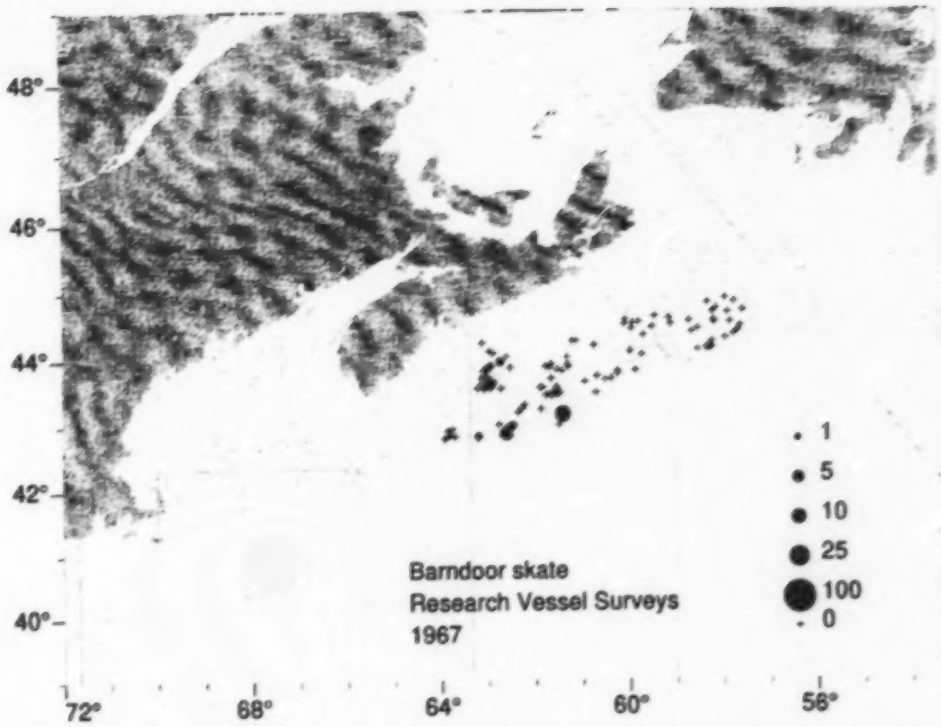
72°
68°
64°
60°
56°
1
5
10
25
100
0
Barndoor skate
Research Vessel Surveys
1966


48°
46°
44°
42°
40°
72°
68°
64°
60°
56°
1
5
10
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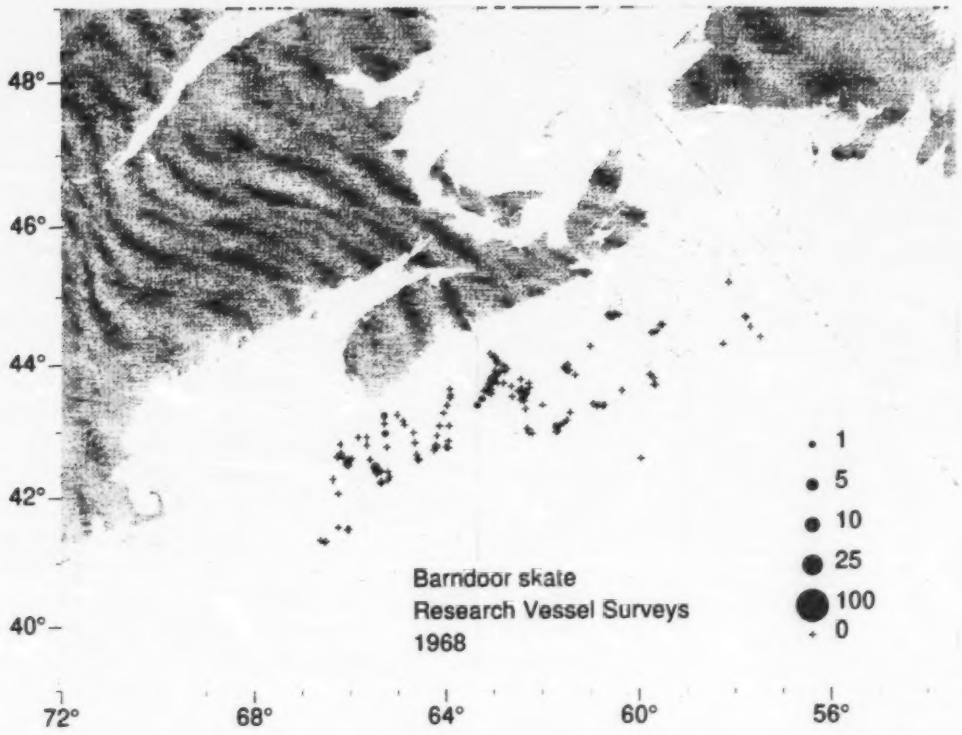
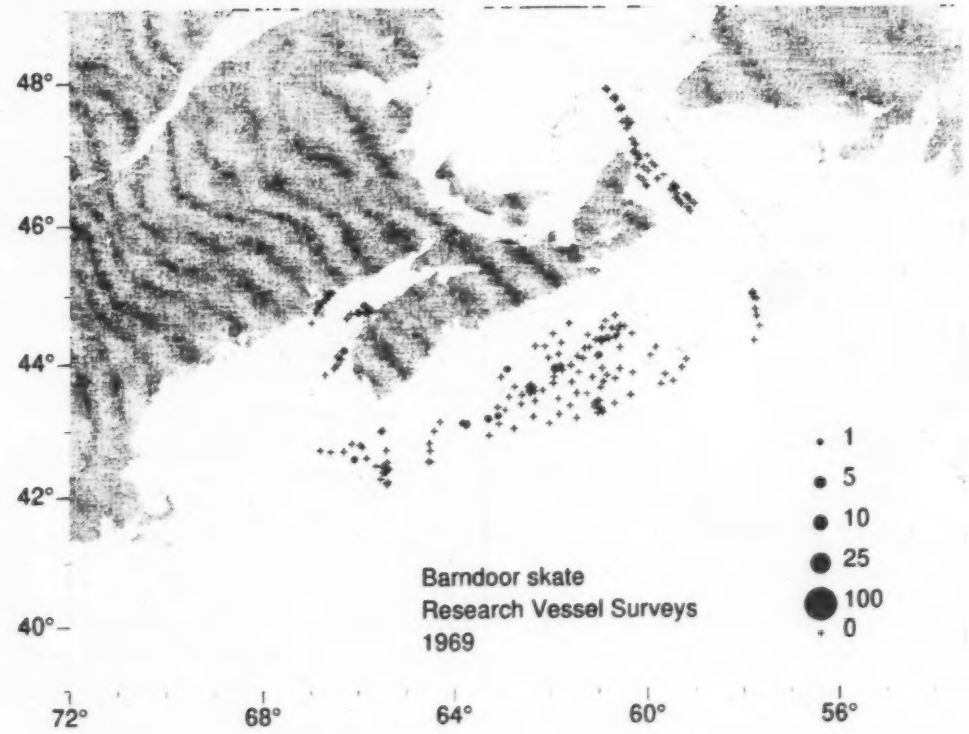
100
0
Barndoor skate
Research Vessel Surveys
1967


48°
46°
44°
42°
40°
72°
68°
64°
60°
56°
Barndoor skate
Research Vessel Surveys
1968
1
5
10
25
100
0


48°
46°
44°
42°
40°
72°
68°
64°
60°
56°
Barndoor skate
Research Vessel Surveys
1969
1
5
10
25
100
0